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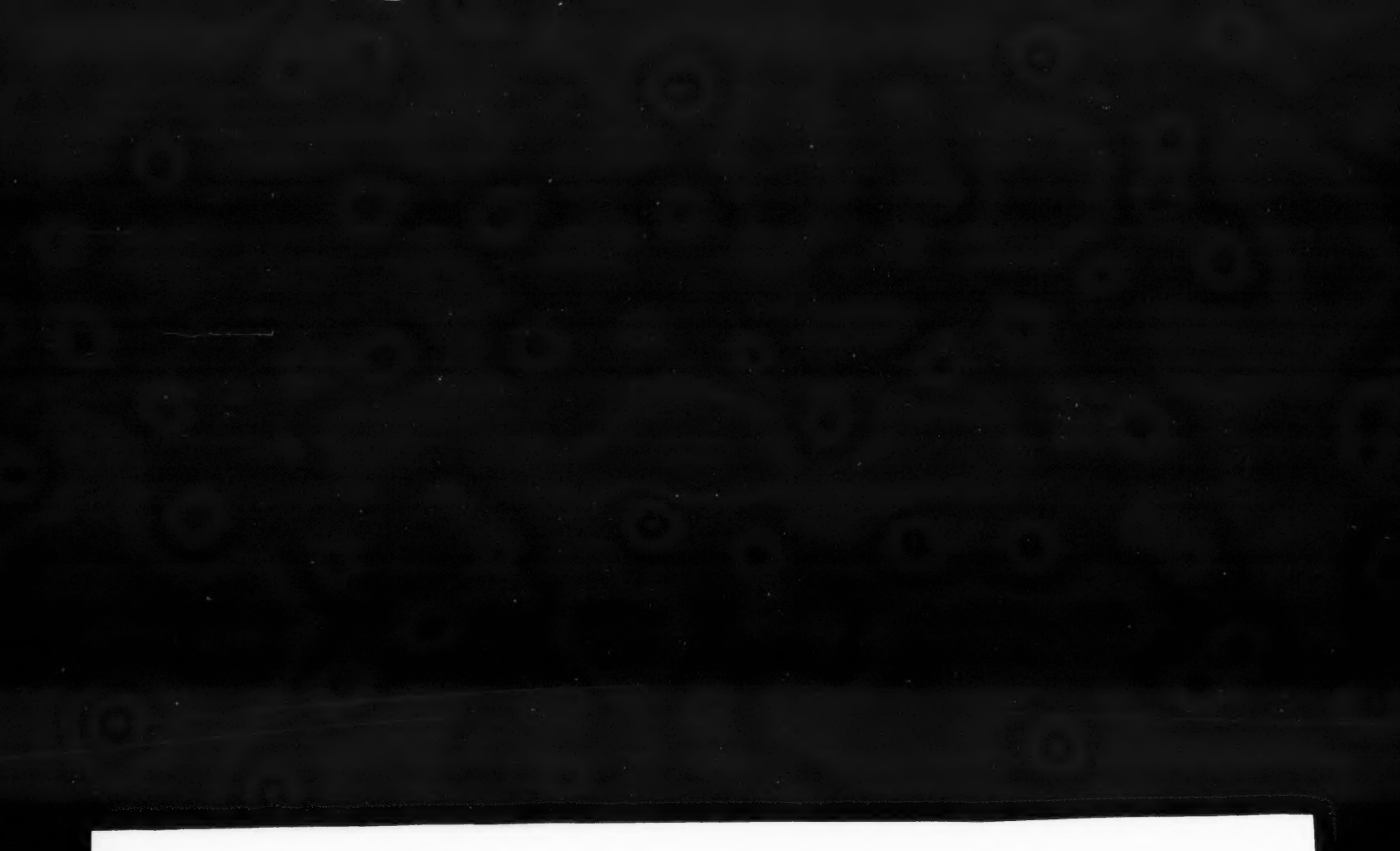

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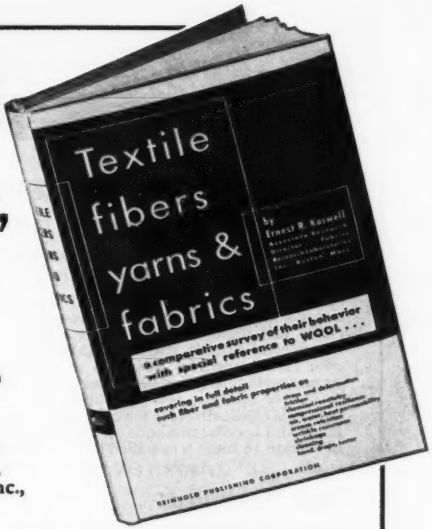

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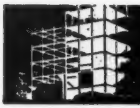

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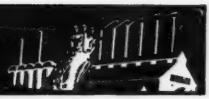
from McGRAW-HILL 

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Do You Know That—

► President Woolrich represented the ASEE at a European Conference on Engineering Education held in London during the week of January 19–23. The Conference was also attended by delegates from Belgium, Denmark, France, Germany, Holland, Italy, Norway, Sweden, Switzerland, and the United Kingdom. Dean Saville and Col. L. F. Grant represented the ECPD at this conference. A report on the conference will be presented at the Annual Meeting at Gainesville. Several European representatives have expressed a desire to form a society for engineering education similar to ASEE.

► From Dr. L. E. Grinter, Chairman of the Committee on Evaluation of Engineering Education, comes the report that the Committee has held three meetings in its comprehensive investigation of the organization, curricular content, and teaching methods of engineering education. A large number of engineering colleges have appointed local committees to cooperate with the ASEE Committee in studying various phases of this program. A contribution of $3,000 has been received from the Engineering Foundation for this project and additional funds have been pledged by the Engineering Societies making up the Engineers' Council for Professional Development.

► A conference was arranged by the ECAC with administrative officials of the Mutual Security Agency (MSA) and the Technical Cooperation Administration (TCA) to discuss the government's foreign assistance programs in the fields of technological education and research. As a means of furthering this constructive relationship, both MSA and TCA have asked ASEE to appoint an Advisory Committee to assist them in future planning. Dr. Ralph Morgen, Program Director for Engineering of the National Science Foundation, is Chairman of the newly appointed Advisory Committee.

► The Report of the Committee on Improvement of Teaching has received high commendation not only from members of the Society, but also from many leading organizations and individuals outside the ASEE. Over 10,000 copies have been sent to engineering colleges for distribution to faculty members. The second printing of this report is nearly gone. Price, 15¢ per copy for less than 100 or $8.00 per hundred.

► A project of considerable significance to engineering education is the program of the Teaching Aids Committee. This Committee is reviewing Teaching Aids in the fields of Civil Engineering, Electrical Engineering, Mechanical Engineering, Mechanics, Physics, and Mathematics. Carl Muhlenbruch, Chairman, says that the bulletin listing Teaching Aids of acceptable quality for engineering instruction will be available about the time of the Annual Meeting in June.

► The ASEE has joined the Engineers' Joint Council under the Council's new plan of expansion to unify the engineering profession. Dean Saville will serve as the Society's first representative. He was elected as Vice President of EJC at the organizational meeting, January 23.

► The Paper Contest announced earlier this year for Young Engineering Teachers has received the enthusiastic approval of the younger faculty members throughout the country. The awards of $200 and $100 for the two winning papers will be presented at the Annual Banquet of the Society at Gainesville, Florida.

► Dean C. J. Freund, Chairman of the ASEE Committee on Promotion of Ethical Standards, is conducting a study to determine the extent to which ethical concepts of the profession have been assimilated into engineering education. A preliminary report will be presented at the Annual Meeting of the Society.

► Did you notice that this issue of the *Journal* contains the first advertisements of teaching positions in engineering colleges and technical institutes? This is a new service to the individual membership of the Society as well as to institutional members. It is hoped that these advertisements might serve not only to place teachers in positions commensurate with their interests and abilities, but also to entice capable scientists and engineers from industry into the teaching profession, thus reversing the recent trends.

► Dean Lampe, Vice-President of ASEE, arranged several conferences between ECAC and ROTC officials last Fall to clarify matters of ROTC policy. This resulted in an official statement of policy by the Airforce ROTC and clarification of Army policy. Dean Lampe also states that the ECAC Committee on Secondary Schools is making significant progress in bringing divergent views to bear upon the problem of High School-College articulation.

► Mr. D. Bridgman, Chairman of the ECAC Manpower Committee, will present an overall analysis of the manpower situation which will consider the effects of increased ROTC quotas, increased Selective Service calls, etc. A problem of grave concern is the prospect of vanishing graduate enrollments, resulting from the combined effects of ROTC and Selective Service.

► The ECAC Committee on International Relations will hold a conference and a dinner meeting at the Annual Meeting of the Society. Invitations are being sent to educators in all foreign lands outside the Iron Curtain.

► Vice-President Eric Walker vows that the ECRC's new Directory of Current Research will be available before the Annual Meeting in June. This year the ECRC will invite Associate Institutional Members to participate in its activities at the Annual Meeting in Gainesville.

► The ECRC Committee on Relations with the Federal Government, Dr. R. J. Woodrow, Chairman, has done yeoman service in keeping deans of engineering colleges and directors of research informed on current research policies and practices of the government.

► The Relations With Industry Division held its semi-annual meeting at Northwestern University, with an attendance of over 300 industrial representatives and educators on January 31. An outstanding program dealing with the recognition and encouragement of potential engineering talent in high schools, the better utilization of engineering manpower, personal motivations in industry, and the continued learning processes of the engineer after graduation, made this meeting an outstanding occasion.

► The Engineering Drawing Division held a highly successful Mid-Winter Meeting January 29–31 at the University of Nebraska. Papers dealt with the opportunities and responsibilities of drawing departments, manufacturing and design problems, and other subjects of interest to drawing teachers.

► The Cooperative Engineering Education Division held its Mid-Winter Meeting at Fenn College, January 22–23. Its "Work-Shop" program consisting of round-table discussions on administrative problems and operational techniques is a highly constructive feature of the Mid-Winter Meetings.

► The Industrial Engineering Division of ASEE is planning a summer school to precede the Annual Meeting at Gainesville. A stimulating and constructive program which will appeal to all industrial engineering teachers is being planned.

► Also, the General Electric Company, in cooperation with the Educational Methods Division of the Society, will again sponsor a summer school, presenting some of the material of the advanced engineering program. This summer school was highly commended by those who attended last year.

► Vice-President W. C. White has announced that preliminary returns on the Conference Programs for the Annual Meeting at the University of Florida are highly encouraging. The Divisions and Committees of the Society have selected program material and speakers which assure a vigorous and constructive approach to the many challenging problems in engineering education.

► The ECRC will have a General Session around the theme "Encouragement of Fundamental Research as an Aid to Education in Engineering," with nationally prominent speakers. . . . The other General Sessions will also be on subjects of vital interest to the membership, and will have speakers of national distinction. . . . A unique feature of the Annual Meeting will be a General Session on Monday afternoon dealing with the principal ASEE projects now in progress. This will include an open-forum discussion to bring the membership into more active participation in the constructive work of the Society. . . . The Engineering Economy Division has arranged a program containing a number of leading economists in industry on subjects of significance to all engineering educators. . . . The Mathematics Division has arranged to have Dr. Curtiss of the National Bureau of Standards, a nationally recognized authority, present several lectures on Electronic Digital Computers. . . . The Atomic Energy Committee is again holding a conference on Atomic Energy Education, a repeat on last year's highly successful conference. . . . More on the Annual Meeting program in the April issue.

► The local planning committee at the University of Florida is doing a splendid job in arranging for facilities and recreational plans for the Annual Meeting. They assure us that they have complete control of the weather in June!

► Vice-President Boring reports that most of the Section Meetings have had larger attendance than any previous meetings and that the programs have been pointed at issues of vital current interest to engineering educators. Most of the Sections have taken active steps to bring younger faculty members into participation in Society functions—a prime objective of the Society.

► A salute to the excellent work of the ASEE Divisions which publish their own quarterly or semi-annual publications—the *Civil Engineering Bulletin, Journal of Engineering Drawing, Machine Design Bulletin, Heat Power News,* and *Chemical Engineering Abstracts.* These are self-financing projects which perform a distinguished service in engineering education.

► Did you notice the new advertising in the *Journal?* Professor Watson, our new Assistant Secretary, estimates the increased revenue to exceed $3000.

► Two new active committees, not previously mentioned, which were appointed this year, are the Committee on Recognition and Incentives for Engineering Education, with Dean E. R. Stapley as Chairman, and the Committee on Improvement of Society Functions, with Dean B. R. Teare, Chairman.

► The Fall Meetings of the ECRC, ECAC, and General Council will be held in conjunction with the Annual Meeting of ECPD at the Statler Hotel, New York, October 15–17, 1953.

► Will see you at Gainesville,

ARTHUR BRONWELL,
Secretary

The Nation's Florida—Everybody's Playground

ASEE Annual Meeting, June 22-26, 1953, University of Florida, Gainesville, Florida

By HAROLD COLEE

FLORIDA *belongs to the nation . . . and to everyone in it.*

The French have a saying, "Everybody has two countries—his own and France." Its popularity as a mecca for tourists has been achieved by the psychology of that kind of thinking. France surrenders to the invasion of its cosmopolitan visitors with a fine Gallic sense of values.

Floridians, too, might well say, "Everyone is a citizen of two states—his own and Florida," . . . for Florida truly belongs to the nation, and to everybody in it. Indeed, it is fast assuming the proportions of an international resort area, welcoming in ever-increasing numbers Canadians and Latin-Americans.

Florida is a national asset—without peer.

Can you imagine America without it?

Picture, if you can, the southeast corner of the United States neatly carved off at a point somewhere north of Jacksonville, curving gently into the northern shoreline of the Gulf of Mexico, with the lush, subtropical peninsula only a misty mirage against the merging blues of the southern horizon.

No Florida? What would our nation be without it—except, possibly, a blessing to cartographers who seem reluctant to map Florida in one piece and without confusing mutilation. Florida is a *united* state, as we boasted in the war year of 1941, and we like to see it united geographically as a bountiful nature conceived and formed it. Surely, it is God's gift to the American people, and to the peoples of *all* the Americas.

Geologists are not precisely agreed on the period of Florida's existence, but we like to think of it as being blueprinted from the very beginning by the Creator; for surely, the mind of man could not conceive it, much as he seeks now to improve it. Geologists do know that Florida was here in the Pleistocene Age from the ancient rock foundation and its gentle steppes of alluvial deposits —as opposed to the theory of sands piled up on fragile coral reefs. No, Florida is the handiwork of the Great Architect, built solidly on the rock of ages to last forever, that untold future generations might, too, enjoy its myriad blessings.

Physically, some see Florida as a tapering finger curving gracefully into the tropical Gulf, pointing southward as a silent invitation to its northern friends and neighbors. Florida *is* inviting, but we in the Florida State Chamber of Commerce like to visualize it as a horn of plenty—a giant cornucopia swinging upward into the broad, open expanse of its northern borders, from which flows the rich bounty of its farms, groves, mines and forests.

Citrus Industry

Gushing forth is a veritable Niagara of golden, health-giving citrus (119 million boxes last year valued at $190 million), a torrent of rich green winter vegetables and other crops of farm and grove; a bountiful flow of forest products: pulp, paper and kraft board . . . a silver

stream of phosphate (70% of the world's total) . . . of limerock and other minerals . . . and the abundant harvest of the sea.

These products of Florida plus an expanding variety of manufactured goods, ranging from native handcraft to electronics, offer ample evidence of the state's balanced economy, of year-round employment and growing payrolls.

Productivity is high because of the healthful, energizing climate; and absenteeism due to inclement weather, dangerous driving conditions and the common cold, is almost unknown.

Florida is a working state, but its greateset claim to fame and largest source of income lies in its incomparable charm as "Vacation-land, U. S. A."

Claim to this tile is due primarily to its unique geographical position between the 31st and 24th parallels, north latitude. We are not, however, technically within the tropics, being one hundred miles north of the Tropic of Cancer. The southern tip of Florida is nearer the equator than any other portion of continental United States. Miami is 500 miles south of San Diego, California. In this insular position between the broad expanse of the Atlantic and broad reaches of the Gulf of Mexico, Florida is bathed with cool trade winds in summer and warm breezes in winter, tempering the extremes at all times.

Another Florida "believe-it-or-not" is: although an Eastern seaboard state, Florida's northern metropolis, Jacksonville, is directly beneath Cleveland and Pensacola below Chicago. A line drawn from Maine's northeast coastline would run 837 miles east of Jacksonville. All of South America lies east of Florida. Thus, Florida properly belongs in the Central Time Zone, but except for Pensacola, we set our clocks with those of the East.

South of the so-called Deep South, Florida is populated largely by Northerners and natives of other states, and the welcomed invasion of new citizens has continued for the past ten or fifteen years at the rate of a thousand a week.

Latin-American Trade and Culture

Florida, too, is near more foreign nations than any other state, and virtually is in the center of the Americas, whose peoples visit here in mounting numbers. Latin-American trade and culture has been developed to such a degree that Spanish is now being taught in the elementary schools of Dade (Miami) and Hillsborough (Tampa) counties. A $40 million Inter-American Cultural and Trade Center will soon be under construction in Miami to strengthen and encourage this good neighbor policy. As a result, the southern peninsula is acquiring a cosmopolitan air and succeeding generations will, in all probability, become bi-lingual, speaking Spanish or Portuguese as well as English.

Florida is big. The tapering formation of the peninsula deceptively belies its true expansiveness—54,262 square land miles, comparable in area to Iowa or Michigan and a trifle larger than New York State. Motorists are sometimes amazed to learn 508 miles separate Jacksonville from Key West—834 miles between Key West and Pensacola; and Pensacola is due west from Jacksonville a distance of 370 miles; and across the state from Miami to Tampa, 260 miles.

"Vacationland"

All of Florida is "vacationland," offering varied charm ranging from the quaint old-south complexion of the northwest counties to the Spanish atmosphere of Tampa and Key West, and the subtropical glamour of the famous Gold Coast. Depending upon individual preference, one will find tourist accommodations to fit everyone's vacation budget.

Florida is host to the nation, last year providing for 4,800,000 visitors and from whom was derived the immense sum of $840,000,000. Where did these people come from? Nearly half of them came from nearby Southeastern states; nearly 20 per cent from Middle Atlantic states

(New York, New Jersey, Pennsylvania); 16 per cent came from Ohio, Indiana, Illinois, Michigan and Wisconsin; and between three and four per cent each from New England, the Southwest, North Central Pacific Coast and Latin-America. Canada and other foreign nations were represented by half of one per cent. Citizens from every state in the union and possessions were registered last year in Florida hotels.

Modes of travel differed but it is estimated that nearly half of the visitors traveled by automobile. Twenty-four per cent, or 1,152,000 came by train; 19 per cent, or 912,000 by bus; and eight per cent, or 384,000 by plane.

. . . Where do these vast numbers of folks stay? . . . How are they housed? . . . fed? . . . entertained? It is a large order, but Florida is geared to it and is constantly expanding its facilities to meet the increased demand.

More than 30,000 hotels, apartment and rooming houses, motels and cottage colonies provide some 575,000 rooms for our visitors; while 13,000 restaurants can seat at one time about 600,000 persons. The daily food consumption would feed an army, and much of it is raised within the state from our own farms, groves and cattle ranges. Catering to the needs, comfort and entertainment of our guests are thousands of cooks, waitresses and other service people imbued with the traditions of southern courtesy whose welcome is always friendly and whose farewell is the invariable admonition, "Come back and see us, he-ah?"

Yes, Florida extends a warm welcome to its visitors in keeping with its climate. Typical Northerners, on their first visit, find it hard to realize that the delightfully balmy air of a warm June night can prevail such a few short air miles from freezing temperatures and knee-deep snow. They marvel at the rich green foliage, the vivid coloring of tropical flowers blooming in profusion through the midwinter months.

The clear blue of the Florida sky banked with billowing white clouds, the star-lit night and brilliant moonlight . . . are revelations in natural beauty to the new visitor. But who has not seen and enjoyed these familiar Florida scences? Despite the millions who have come here and the thousands of newcomers attracted each year, new generations will continue to come and marvel to the end of time.

Summer Vacation Spot

When it's June in January many new visitors ask, "What must it be like in July and August?" A logical process of reasoning leads to the belief that the weather must naturally become increasingly warmer through the spring and summer; but this is not true—as millions of summer vacationers have happily learned. Paradoxically, "fabulous Florida" is warm in winter, cool in summer . . . like the ancient fable of the man who blew to warm his hands and blew again to cool his soup. Florida winds do both.

Have you ever seen newsphotos of Floridians sleeping on fire escapes or in public parks to avoid the heat? Have you ever heard of sunstroke or heat prostration in Florida cities? No, never, because the Peninsula State is air-conditioned by nature; and the system never fails. Summer nights are cool following the hottest day.

Occasionally sumer heat waves from the North and West penetrate into the Florida peninsula, as do nation-deep cold fronts of winter; but when it is uncomfortably warm here, it is invariably warmer there, and when it is chilly here, it is much colder there. This statement can be verified in the weather report in your daily newspapers.

Known the world over as a delightful winter resort, Florida is becoming equally famed as a summer vacation-land with an increasing number of visitors arriving during July and August. Last year nearly 1,500,000 tourists came here in midsummer to enjoy themselves for rest, recreation and physical refreshment.

The summer season offers many more

Florida's 3,800 square miles of inland water makes an ideal playground for the small boat owner and ardent fisherman. Bass, bream and crappie fishing will reach the peak in Florida during the winter months.

attractions, much more in the way of sports and entertainment and at a considerably less cost than at the peak of the winter season. The beaches of Florida's nearly 2000 mile salt-water shoreline are at their best, crowded with carefree vacationers from sun-up until dark. Fishing is also at its peak in summer months in some 30,000 fresh water lakes and rivers, as well as for deep-sea angling and the popular surf-casting. Recreation centers, resorts and attractions are crowded with vacationers. All Florida seems to take on a carnival air in summertime as thousands of pleasure-loving Floridians join their visitors in enjoying themselves in the great out-of-doors.

Seasonal fluctuations are less noticeable in recent years, and spring and fall vacations are growing in popularity. Autumn holds special appeal for the hunter aware of the variety of game birds and other wildlife with which Florida abounds. The early flights of waterfowl and other migrant game birds provide good shooting and limit bags for visiting nimrods. Many others come to this state before the advent of wintry weather and to avoid the chill gray days of October and November. They have learned, too, that the early visitor finds a better choice of accommodations and that seasonal reservations are usually more economical.

Easter vacation periods bring an influx of families during the school holidays as a preview of summer and to break the monotony of prolonged northern winters. In fact, the Florida tourist season seems to continue uninterruptedly around the calendar. Each year the so-called winter season seems to start earlier and last longer; while summer business is beginning to show signs of extending from Spring to Fall.

Where to Go and What to Do

Whatever the season, newcomers are often perplexed as to where to go and what to do. If they have written the State Advertising Commission, the State

Chamber or local chambers of commerce for literature, they are probably overwhelmed with the multiple attractions described on the East Coast and Central Florida and in the historical Northwest. Truly, one section of the state seems to offer more attraction than another—even discounting the usual superlatives of travel folder descriptions. Much depends on your tastes.

Season visitors to the West Coast look down their noses at East Coast devotees —and vice versa. Big city fans who enjoy metropolitan attractions cannot understand people who "bury themselves" in small interior towns. South Florida regulars scoff at those who prefer North Florida areas, and so it goes ad infinitum. Personal preferences, happily, distribute the millions of visitors fairly evenly throughout the state, according to individual tastes.

The State Chamber, like a doting father with many children, has no favorites, recognizing in each section of the state certain regional advantages and few, if any, faults. However, the visitor able to do so should try to see all Florida before deciding definitely where to stay. This is especially desirable when contemplating permanent residence here.

Throughout the state, vacationers will find an unbelievable variety of interesting things to see and do. For the nature lover, Florida can offer some of the most beautiful sub-tropical scenery in the world—glistening beaches, graceful palms, gay exotic flowers, bright clear skies and sparkling waters.

From the beaches of either coast it is but a few minutes drive to the great stretches of state parks where nature, untouched, offers scenes of primitive grandeur. More than 30,000 named lakes, and streams provide unparalleled fishing and boating. No matter what season of the year, you will find a great variety of things to see and do. Sports fans will find the season full with major events: regattas, racing, rodeos, golf and tennis tournaments, swimming meets and major league baseball games. Florida's pageants and festivals are world famous, and run through the calendar in various parts of the state. Attendance at such festivities is not costly and many of them are free.

Motor Trips

A motorist approaching along the Atlantic coast will find numerous interesting spots and stops: Fernandina, site of some of Florida's most colorful history; Jacksonville, northern metropolis; St. Augustine, America's oldest city, with its ancient Spanish fort and historical building, its alligator and ostrich farms, and museums; Marineland with its trained porpoises and vast display of live marine life; Daytona Beach, where auto and motorcycle races are run on the broad smooth sands; numerous lovely tropical gardens; beautiful beach resorts, the Palm Beaches and the Gold Coast's famed Miami area cities and suburbs, offering inexhaustible sources of interest and enjoyment.

One of the most unusual motoring trips is that from Miami to Key West over 122 miles of the famed Overseas Highway. This roadway, which is actually a series of bridges from key to key, passes over more water than land on its course to Key West. There is excellent fishing along the way, and many places for pleasant stopovers while enjoying the journey. Unusual food is available in this section: turtle steaks, conch chowders, and lime pies being among the favorites of the epicure. The lower keys are steeped in legends of lost Spanish gold, and buried pirate loot. The Spanish Flotilla, the Great Treasure Fleet of the Conquistadores, had ships wrecked on the ragged reefs of these waters. Millions in gold were reputed to have been lost and the seagoing hijackers of a later period are believed to have cached much booty on lonely little keys now crossed by the unique motor seaway.

Everglades National Park

One of the most unusual attractions in America is the Everglades National Park. This vast wildlife sanctuary can be reached via U. S. Highway 1 south to

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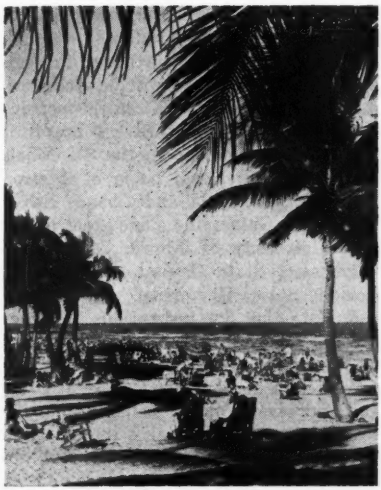
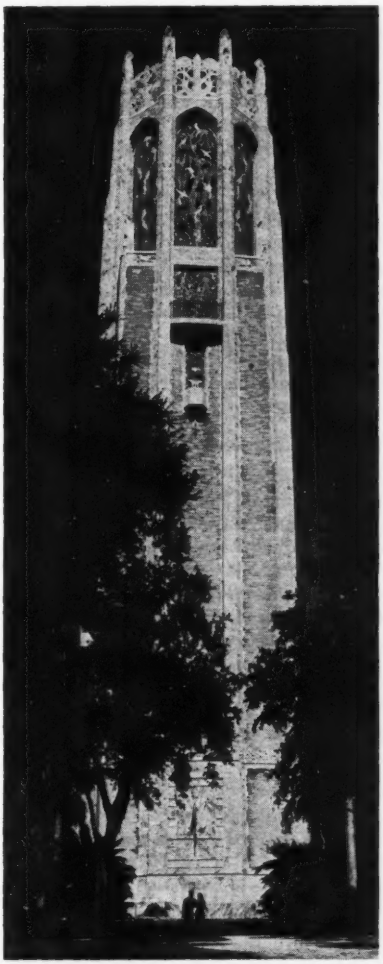


MIAMI BEACH, Fla.—Palms, sea, and sand, along with the famous Florida sun make this fabulous beach a Mecca for winter and summer visitors.

Homestead where well-marked trails lead the visitor to the numerous points where there are nature walks. In winter it is possible to observe much of the park's native wildlife—alligators, egrets, water turkeys, wood ibis, pelicans, deer and other game. The jungle-like, subtropical vegetation holds great fascination for the visitor; such trees as the gumbo-limbo, paradise tree, and strangler fig; and wild orchids and native ferns which abound in this natural setting. Audubon Wildlife tours are conducted from Miami to the park during the winter season, and bus lines include a portion of the park in special tours.

Crossing the state from Miami to the Gulf Coast along the Tamiami Trail, the traveler passes through Everglades country. On either side of the highway is a great sea of saw grass and palmetto. A short way off the highway, the interior will often reward the nature lover with a view of rare flowers and tropical birds. Arriving at Fort Myers, once the winter home of Thomas A. Edison, one finds a beautiful city celebrated also for its sports fishing. A visit to Edison Gardens is a pleasant interlude, featuring unusual



LAKE WALES, Fla.—Florida's Singing Tower is a memorial to Edward W. Bok, noted journalist and Nobel Prize winner. The area surrounding the tower is a bird sanctuary and garden. The tower's carillon of 71 bells is played for concerts during the winter season.

tropical plants collected from the faraway tropics by Mr. Edison himself.

Sarasota, winter home of the great Ringling Brothers circus, is also the site of the Ringling home and Museum of Art, the latter willed to the State of Florida by the late John Ringling. In this central Gulf section, facing each other across the bay, are two of Florida's most charming vacation cities, St. Petersburg, and Tampa. Northward from this point stretch miles of unspoiled native scenery.

The visitor will not wish to miss the central section of the peninsula. Here in the rolling hills are miles of sweet-scented citrus groves, packing houses and processing plants. Miles of rich pasture land support Florida's huge cattle industry, famous for its humped-back Brahman crossbreeds, truck farming and dairy business.

The Central Interior

In the central interior of the Ridge Section may be found delightful scenic splendor and attractions, including the Bok Tower at Lake Wales. The 71-bell carillon presents concerts through the winter season. Within the same area is a new attraction, *The Great Masterpiece,* a huge mosaic reproduction of Leonardo da Vinci's magnificient painting, *The Last Supper.* Cypress Gardens at Winter Haven puts on breath-taking water ski shows daily in a beautiful setting of tropical shrubs and colorful flowers known as a photographer's paradise.

The motorist driving northward through the center of the state will be richly rewarded with visits to the central metropolis of Orlando; Sanford on beautiful Lake Monroe; and on up the St. John's riverlands to DeLand, home of Stetson University; to Ocala and famous Silver Springs; to Gainesville made great by the great University of Florida, and on to Tallahassee, State Capital and home of Florida State University and Florida A. & M. Other fine institutions of higher learning are the University of Miamo and the University of Tampa, Rollins College at Winter Park, Southern College at Lakeland and several junior colleges and private schools. Florida takes its education seriously and is expanding its facilities to meet the demands of its mounting population and out-of-state students.

Florida, with all its advantages, holds magnetic attraction for old and young: for the scholar, the sportsman, the motorist, the businessman, farmer and those of the professions, offering almost unlimited opportunities in multiple fields of endeavor plus the advantages of favorable tax laws, friendly to business enterprise with the added bonus of what we believe is the world's best and most equitable climate. Native Floridians feel it is simply too good not to be shared with others. That is why we call it "The Nation's Florida."

Third International Conference on Soil Mechanics and Foundation Engineering

The Third International Conference on Soil Mechanics and Foundation Engineering will be held in Switzerland this summer. The first part will take place in Zurich on August 16–21 and the second part, August 22–25, includes a four days' tour through Switzerland to afford the opportunity to see not only points of interest for geotechnical and foundation engineering, but also something of the country's natural beauty. The final session will convene on August 26 at Lausanne on Lake Geneva. All correspondence relative to the Conference should be addressed to Dr. A. von Moos, General Secretary, Gloriastr. 39, Zurich 6, Switzerland.

Thoughts on Contemporary Problems*

By JOHN SLOAN DICKEY

President of Dartmouth College

President Dickey extended a cordial welcome to the members of the ASEE and said that he wished to speak for a few minutes about "the purpose of higher education and the reconciliation of what we are pleased to call the liberating arts and the technical, professional studies with which you are primarily concerned."

Mr. Dickey stated that his predecessors had dedicated Dartmouth to the proposition that its ultimate obligation is to human society. Mr. Dickey said if the ultimate obligation of the liberal arts college is to serve human society, the college must look out into that society and ask what is the central need of that society today.

"The central need of human society today is to bring into better balance the utter physical power which we now possess and the moral and political controls of that power. For the layman this need can be emphasized by considering that since 1900 the destructive power in the hands of men has increased by something like four million times. How much have we increased our moral and political controls over the use of such power since 1900? We need *better* balance between physical power and its moral and political controls. We are not confronted with the problem of discovering some new moral, political, economic or social truth. Indeed, if that were the case, the time factor is such that we had better just relax and have as comfortable a time as we can until this thing blows up."

"The central factor in the problem of getting this better balance is the time factor. The history of the human race indicates that, given time, men have been able to develop the moral and political controls necessary to the power that they possessed at any particular moment in history—whether the power was represented by slings, bows and arrows, gunpowder, or the six-shooter on the frontier."

Mr. Dickey suggested, however, that it is just possible "we have turned one of those few right angle corners in human affairs." He said, "Now, for the first time, men and nations have the power which can make their mistakes and their evil complete and irretrievable as far as this particular industrial civilization is concerned." If this is true, he said, then we can no longer rely on the proposition that time cures all things.

Speaking once more of the central need of society in relation to the purpose of the liberal arts college, Mr. Dickey said that men working in education must cling to the idea that the time factor in human affairs is not absolute and has never been absolute. "The time factor in human affairs is relative to the will and the capacity of men to serve the public good regardless of how they serve their own individual welfare. The liberal arts college is concerned more than any other institution of higher education with developing *both* the will and the capacity to serve the public good. The combination of will and capacity is the essence of leadership. Whenever your business, whenever your profession, whenever a

* A report of informal remarks delivered before the ASEE in Hanover, New Hampshire, June 25, 1952.

nation or any other human group has had a tough, large, seemingly insoluble problem, at the core of which was a time factor of urgency, the one thing that human experience indicates could be turned to is this thing which we call leadership. The principal historical justification for leadership is its utility in countering the time factor in human affairs."

In conclusion Mr. Dickey emphasized the importance of developing man's capacity for action. The will is useless without the capacity—"only as men see a way to do things can they sustain the will to do them. I suggest to you," he said, "that there's no profession more concerned than engineering in this industrial society with supplying the capacity for action."

Intensive Course in Automatic Control

The University of Michigan College of Engineering has announced two Intensive Courses in Automatic Control. The first is scheduled for June 15 to 20, 1953, inclusive, and the second for June 22 to 25, 1953, inclusive. The courses are intended for engineers who find it necessary or who wish to obtain a basic understanding of the field, but who cannot spare more than a few days for this purpose. The purpose of the course is to make it easier to learn by a coherent presentation of the fundamentals of modern automatic control and by providing a comprehensive set of notes to serve as a framework for further study.

The courses are built around the principles and application of measurement, communication and control. Course I will consist of the fundamentals in each of these fields and will include some fundamental work in non-linear systems. Course II will take up applications of the fundamentals to more advanced problems. There will be four hours of lecture each morning and three hours of demonstration in the afternoon. Extensive use will be made of computing, instrumentation and servo laboratories on the campus. The role of analog computing methods will be emphasized.

Further information may be obtained by writing to Professor M. H. Nichols, Room 1523, East Engineering Building, University of Michigan, Ann Arbor, Michigan. April 15, 1953 is the closing date for registration.

The Air Research and Development Program*†

By COLONEL O. G. HAYWOOD, JR.

U. S. Air Force

I appreciate this opportunity to present to the American Society for Engineering Education the broad aspects of the scientific program of the Air Research and Development Command, and to cover views of the Air Force as to its expected impact on university teaching and research.

The Air Research and Development Command is a relatively young organization. Top Air Force officials have long recognized the need for effective coordination and administration of the Air Force's far flung and widely-varied research and development activities. Three years ago, a special committee was appointed to study this problem. The committee was composed of university and industrial leaders, under the chairmanship of Dr. Louis N. Ridenour, then Dean of the Graduate School, University of Illinois. The Ridenour Committee recommended separation of research and development activities from materiel procurement—in other words, separation of responsibility for the quality of Air Force materiel from responsibility for the quantity procured. This concept was accepted by the Air Force, the Air Research and Development Command was established, existing research and development facilities and projects were assigned to it, and the command became operational as a major Air Force Command a year ago this Spring.

Many of you are intimately familiar with Air Force installations which have been consolidated to establish the Air Research and Development Command. Under the Headquarters of the Command, at Baltimore, Maryland, are eight field commands called Centers: The Wright Air Development Center, at Dayton, Ohio; Cambridge Research Center at Cambridge, Mass.; Rome Air Development Center, Rome, N. Y.; Arnold Engineering Development Center, Tullahoma, Tenn.; Flight Test Center, Edwards, California; Missile Test Center, at Cocoa, Florida and Alamogordo, N. M.; Armament Center, Eglin Air Force Base, Florida; and the Special Weapons Center at Albuquerque, N. M.

I would like to emphasize that, with a few exceptions such as certain studies in the bio-sciences at the School of Aviation Medicine, all research and development activities of the Air Force are under the command control of the Headquarters of the Air Research and Development Command at Baltimore. The entire program is prepared as a single, coordinated document, by personnel familiar with industrial engineering and research, university facilities and talents, and the Air Force's own laboratories.

The details of the program must remain secret, for obvious security reasons, and would be too complex for presentation here in any case. A few statistics on the general program may be of interest. The appropriation bill now before the Congress provides for direct research

* An address to the American Society for Engineering Education, at Dartmouth University, June 24, 1952.

† Provisions for support of publication of results of Government sponsored research were eliminated by the Congress before enacting HR 1180 as PL 557.

and development costs, in Air Force laboratories and by contract to other institutions, of approximately $600 million.

Allocation of Funds

A relatively small portion of this total is devoted to improvement of equipment and systems in the active inventory—our aircraft in operation in Korea; ground handling equipment; the multitude of items from blouses to B-36's which constitute Air Force materiel.

The bulk of the funds go into development of equipment and components which are combined into weapons and weapon systems to satisfy a specific operational requirement. For those not familiar with the term "weapons system," I might cite an example: a night jet interceptor complete with all its instruments, ordnance, fire controls, communications, and radar, together with the ground-handling equipment to keep it airborne and the ground electronic equipment to find the enemy and vector the interceptor into contact. The core of the program is oriented toward the requirements of weapons systems. The weapons systems match the operational responsibilities of the Air Force. The requirements of each system are determined from a weighted evaluation and judgment between the technical quality desirable for superiority over probable enemy weapons and the quality possible within the funds and time available.

A much smaller portion of the total funds is reserved for supporting research and development—the development of a new vacuum tube, or a better propeller, or a superior fuel.

Finally, a still smaller portion, actually about two per cent of the total, is devoted to basic research—fundamental investigations in those fields of the mathematical, physical, earth, and life sciences upon which rest our whole Air Force technology.

Going back to this figure of $600 million for research and development, we may break it down another way. Roughly, 10 per cent goes for direct costs of research and development laboratories of the Air Force, about the same amount goes to universities, and the remaining 80 per cent goes principally to industry. By direct costs of Air Force laboratories, I mean scientific equipment; laboratory supplies; and salaries of scientific, technical, administrative, and maintenance civilian personnel engaged in actual laboratory operations. Other costs of the laboratories are covered by other funds.

A portion of the 80 per cent going to industry is subcontracted to universities. Obviously such funds are almost entirely for applied research in furtherance of industrial requirements generated by Air Force contracts. The contract policies are established by the industrial concerns involved, and are not different from industrial-university relationships that have existed for years, except that the amount of money involved is greater than, say, twelve years ago before the Second World War.

About 10 per cent of the total research and development funds reach universities under direct contracts from Air Research and Development Command laboratories and offices. At the present time, obligations under active contracts with universities and university-affiliated research institutions total more than $120 million. The current annual level of support is approximately half this amount. The program covers a broad cross-section of American universities. It includes 107 universities in 33 states, the District of Columbia, Alaska, and Puerto Rico.

$120 million is a good deal of money, even to the Air Force. It is a good deal more to the universities. The Steelman Report to the President, Science and Public Policy, estimates that the total national research and development budget in 1930 amounted to $166 million. By national is meant not national government, but all expenditures within the nation—in government laboratories, in industrial laboratories, in universities. The national research total budget in 1930 is not greatly in excess of what the Air Force alone now has under obligation to uni-

versities. It is decidedly appropriate that both the universities and the Air Force study the impact of such work on the normal research and teaching activities of our universities, and take action to mitigate undesirable consequences.

Last November, the Air Research and Development Command established at Command Headquarters an Office of Scientific Research. I have been the Chief of this Office since it was organized, reporting directly to Lieutenant General Partridge, Commanding General of the Air Research and Development Command.

Need for Basic Research is Recognized

This Office was established in recognition that air superiority in the future is dependent upon adequate basic research in the present. The needs of national defense have created the present situation in which research and development expenditures of the national government exceed those of all of the rest of the U. S. economy combined. Government programs dominate, or at least greatly influence, the structure of the entire national research effort. In the past, the Air Force has concerned itself primarily with application of known scientific laws and principles to the technology of air warfare. It has built upon the existing foundation of basic scientific knowledge, it has depended on the universities to strengthen and expand this foundation. In the future, the Air Force must give more active support to basic research in those fields of science which provide the base for Air Force technology. This is the mission of my Office.

We approach this mission in two ways. First, we exercise general supervision over the basic research programs of all of the Centers. Second, we support directly a modest program of basic research in universities. (Perhaps I should define our meaning of the term "basic research." By basic research, we mean fundamental investigations which are supported because of their probable contribution to advancement of scientific knowledge when we have no specific Air Force problem or application in mind.)

There are many reasons why government funds should be made available in these times for support of basic research in universities. There is only one reason, however, why Air Force funds can and will be so used. The support of basic research in fields of science of interest to the Air Force is consistent with and in furtherance of the purpose for which the funds are appropriated to the Air Force—to develop and maintain qualitatively superior air power. If I may use the words of an almost antiquated economic theory, it is in the enlightened self-interest of the Air Force to support basic research in universities.

Let us return now to the university program as a whole and look at the effect on the universities. Of the present total of $120 million, slightly over half is classified work. However, three-fourths of the classified work is in six institutions, which have established contract research affiliates or separate projects so that the classified work does not intermingle with the academic teaching load.

About $55 million supports unclassified research in universities. Between one-third and one-half of this could be considered basic research, from the Air Force point of view and definition of the term. This portion of the program should be definitely beneficial to the universities, since it is simply adding to the type of research which is historically a role of universities and an essential adjunct to education at the graduate level.

A sample survey of basic research contracts indicates that each $100 thousand of Air Force funds supports in salaries four part-time predoctoral students, one full-time predoctoral research worker, two part or full-time postdoctoral workers, as well as part-time support of faculty members.

The number of predoctoral students receiving part-time Air Force support while pursuing graduate studies is considerably in excess of the 569 predoctoral students in the FY '53 fellowship program

of the National Science Foundation. The Air Force as a matter of policy encourages participation of graduate students on a part-time basis in Air Force basic research contracts.

Support Training of Graduate Students

Here again, this interest in supporting training of graduate students in the enlightened self-interest of the Air Force. These personnel are required for the effective prosecution of the research projects. Moreover, expanding the pool of trained scientific manpower in fields of science supporting the Air Force is strengthening the Air Force of the future. Few of these men will come into actual Air Force employment. It directly helps the Air Force, however, when these young scientists enter into industrial projects or university research for the Air Force, or simply join the pool of trained scientific manpower making other individuals available for Air Force-sponsored work.

The Air Force naturally expects to receive a portion of the university output of technical personnel. Approximately 450 second lieutenants will enter the Air Research and Development Command this June from university ROTC units. About two-thirds of these young lieutenants have scientific or engineering degrees. Judging from past experience, a few graduate students, including those who have been aided in their education by part-time employment on Air Force contracts, will accept commissions in the Air Force. A larger group will be required for civilian positions with Air Force laboratories. The Air Research and Development Command is planning a modest increase in requirements for civilian technical personnel over the next two years, of the order of 5 per cent each year. It anticipates no undue difficulty in meeting this requirement, although it would appreciate any assistance you gentlemen as educators can give in acquainting students with Air Force manpower needs. Incidentally, the Air Research and Development Command has just completed a brochure outlining the job opportunities with the command for technical personnel. Copies of this brochure will be mailed to universities within the next month.

In addition to payment of student and research workers' salaries, Air Force contracts finance research facilities, equipment, and supplies which are often of value in connection with university educational programs and would not otherwise be available. Finally, the part-time employment of faculty members, either in research projects, particularly during the summer months, or as consultants on research programs, adds to the emoluments of such personnel and helps to close the gap between the salary scales of universities and industry. I recognize that this last statement is applicable in varying degrees to different universities, is somewhat controversial, and is a matter for policy determination by the universities rather than the Air Force.

In keeping with standard university practices, the Air Force encourages publication of papers on its unclassified projects, and on classified projects to the extent permitted by security considerations. As Faraday said, there are three stages to research: to begin it, to complete it, and to publish it. Under government regulations, the Air Force must have a report on a research project before it can authorize final payment. However, in the interest of dissemination of scientific knowledge, and frankly to encourage better-written reports, the Air Force accepts in lieu of the final report, a copy of a manuscript covering the work which has been presented to a professional journal. I might add that the Air Force at the present time does not have authority to support such publication in technical journals. The Air Force is actively supporting HR 1180, a bill passed by the House and currently awaiting action in the Senate which would permit among other things support of publication of research results.

I have commented at some length on what the Air Force is doing to provide a more effective partnership with uni-

versities. I do not mean to imply, however, that we consider our part done or even well underway. We intend to continue study of this problem of strengthening the universities as research and educational institutions while we strengthen the Air Force as a fighting machine. For increased effectiveness in this Air Force-university relationship, we will unquestionably need increased participation of university personnel in planning and in management of the university program of the Air Research and Development Command.

I might add for the benefit of those not closely associated with the Air Force program that the Air Force has enjoyed for years the active assistance of university personnel. I have already mentioned that the Air Research and Development Command had its genesis in the report of a committee headed by Dr. Ridenour, then of the University of Illinois. Several other university personnel served on this committee, including Mr. Ray Woodrow who will preside at this afternoon's session on "Trials and Tribulations in University-Government Contract Procedures." My office has been aided in getting underway by the Panel on Physical Sciences of our Air Force Scientific Advisory Board. This panel, headed by Dr. George Kistiakowsky, Professor of Organic Chemistry at Harvard University, advises on the broad aspects of our program of basic research. Dr. Francis H. Clauser, Professor of Aeronautical Engineering at the Johns-Hopkins University, has associated himself closely with the office on a part-time basis, as my senior scientific advisor. Dr. Paul Flory of Cornell University is chairman of our Chemistry Advisory Committee. We are in the process of establishing similar committees for the other fields of science in which the Office of Scientific Research has comprehensive programs.

Active University Participation

I emphasize this active university participation in the formation of the Air Research and Development Command, and in the current activities of my Office, in the hope that many of you gentlemen will also be willing to contribute actively to the Air Force program. We must recognize that the universities of the Nation have become as essential to the Air Force research and development programs as Air Force operated laboratories. Research requires stability. This is a major problem in government-sponsored university research. Obtaining this necessary stability requires study and action by both the Air Force and the universities.

Three years ago, a faculty committee of the Massachusetts Institute of Technology completed an educational survey. The report starts with these words: "Final reports are the traditional monuments to the labors of committees, and too often serve only as a burying ground for ideas." In conclusion, I quote these words and express the hope that the ideas generated here today may bear fruit in more effective Air Force-university relations. The research requirements of the Air Force and the research and educational goals of the universities must be attained in harmony, not in conflict. We ask your active help toward this end, in our interest and in yours.

New and Specialized Laboratories of the Department of the Army*

By MAJOR GENERAL K. D. NICHOLS

Chief of Research and Development, Office of Chief of Staff, U. S. Army

It is indeed a pleasure to participate in this Panel discussion of "The Impact of Government Sponsored Laboratories on University Teaching and Research." The particular subject that has been assigned to me is "New and Specialized Laboratories of the Department of the Army." In assigning this subject your Executive Committee assured me that the title was broad enough to permit the widest of latitude in my comments. So, with that leeway, I would like to precede any discussion of new laboratories with a more general discussion of what we are trying to accomplish in the Army Research and Development Program.

The objective of our Army Research and Development Program is to exploit all avenues of modern technology to achieve the highest possible effectiveness for our ground forces, always keeping in mind that we have a paramount requirement that this effectiveness must be obtained with a minimum drain on our national resources. Our application of modern technology to war is not limited to the development of better equipment but we are also applying modern technical methods of analysis and research to determining the best way to utilize our equipment and manpower. Our efforts are being devoted to determining how we can accomplish the Army's mission with the minimum losses and at the minimum cost in dollars, talent and material.

Two of the primary problems involved are how do we reduce our losses and how do we make up for our deficiencies in manpower in facing Communist hordes by equipping our manpower with the most effective equipment and determining the best doctrine and techniques for its use. To achieve a reduction of losses is a real challenge to the military and to the technicians in finding ways and means of putting the Army on a par with the Navy and the Air Force. Analysis of losses in the last war and in the present fighting in Korea reveals that the ground soldier suffers some 80–90% of the total casualties.

As a result of this challenge, the Secretary of the Army and the Chief of Staff have been devoting a great part of their effort to insure that the Army Research and Development Program is given the proper emphasis. As an aid to insure proper emphasis. research and development in the Army was recently reorganized to place the Chief of Research and Development at high enough level in the Army organization to have direct access to the Deputy Chiefs of Staff, the Vice Chief of Staff, the Chief of Staff, and the Secretarial level of the Army. In addition, all parts of the General Staff are actively participating in the Research and Development Program. In addition to hardware research which remains with the Technical Services, greater emphasis is being given to operational research, research for development of new techniques and basic research.

This reorganization is continuing down

* (Discussion at the Annual Meeting of the Engineering College Research Council of the American Society for Engineering Education at Dartmouth College, June 24, 1952.)

into the Army Field Forces where we are planning to set up a development organization for testing new weapons and developing new techniques and doctrines, as well as establishing a special weapons command for solving in the most expeditious manner the training, tactical and doctrinal problems related to Army use of atomic weapons and guided missiles.

Another objective of the Research and Development reorganization was to insure closer liaison between strategic planning and research and development. This is a two-way proposition. We must not only insure that our strategic plans for the future recognize the possibilities of our Research and Development Program but at the same time we must adjust and orient our Research and Development Program to be in accord with our strategic planning.

Utilization of all Talents Available in Primary Problem

In our efforts to achieve the most efficient weapons and techniques for using them, we recognize that one of our primary problems is how do we combine and utilize to best advantage all the talents available to us. In the development of a new weapon the optimum weapon is achieved when we utilize to best advantage the talent, experience and know-how that are available in the Army Field Forces which is the ultimate user, the Army Technical Services, industry and universities. No one of these groups by itself can achieve the best weapons nor can any one of these groups dictate what is the best weapon or the best way to use it. Like so many other things in life, accomplishment here rests on making the user, the Technical Services, industry and academic technicians work together as a team.

The variety of laboratories that the Army has and is building and the variety of our contracts illustrate that there is no one best way to achieve this optimum blending of talents. The procedures best suited for developing a rifle are not the best for developing a new or novel weapon such as the atomic bomb or the proximity fuze. The result is that we have various types of laboratories—some of them are government-owned and operated such as those with which you are all familiar as at Fort Monmouth, Aberdeen, and Edgewood Arsenal.

In addition to these old, well-established, government-operated laboratories, we have the relatively new laboratories at Camp Detrick, Maryland, operating under Chemical Corps jurisdiction, and the laboratories at Redstone Arsenal, Alabama, for guided missiles, operating under Ordnance jurisdiction. We hope to build a Quartermaster Laboratory at Natick, Massachusetts. In addition to government-owned and government-operated laboratories, we have created several government-owned laboratories that are operated by either universities or industries. In the guided missile field one of the most outstanding laboratories that is government-owned and university-operated is the Jet Propulsion Laboratory operated by California Institute of Technology in Pasadena. This laboratory, operated under contract and under the most competent direction of Professor Louis G. Dunn, has made outstanding contributions to our guided missile program. In a similar manner guided missile work has been conducted in government-owned and contractors' facilities by the General Electric Company and by Bell Telephone Laboratories. These are cited as typical examples and are not intended to be all-inclusive of installations or of our program. Also, the Army guided missile program represents the varied ways of contracting and allocating responsibilities in order to get the job done. For example, for one missile the Jet Propulsion Laboratory at California Institute of Technology has done the research, development and engineering, and Firestone Tire and Rubber Company is responsible for production.

For another outstanding missile Bell Telephone Laboratories and Western Electric Company have had complete re-

sponsibility for research and development as well as production. They have been assisted by Douglas Aircraft and other subcontractors. At Redstone Arsenal the Army Ordnance is utilizing many of the German scientists who were responsible for the German guided missile program during the last war. This civilian-military organization is assisted by several industrial contractors.

In addition to research and development on basic hardware items such as guided missiles, tanks, artillery, munitions, etc., wherein academic resources are being employed to assist the Research and Development Program, the Army has turned to the scientists for assistance in solving operational problems. Several years ago we asked The Johns Hopkins University to staff and administer an Operations Research Office, borrowing from educational institutions qualified scientists that we might have them apply technical analysis to our more difficult operational problems. I regret that we have to be in competition with education to get a qualified staff for the Operations Research Office but I can assure you that the end justifies the means. The ORO has already proved invaluable in furnishing analyses of operational problems to assist in important command decisions. It is surprising how an intuitive appraisal of comparable value of weapons and weapons systems can be reoriented by a careful, detailed evaluation of effectiveness, operating costs and required logistic support.

For example, it has long been the dream of every antiaircraft artillerist that we could develop a radar acquisition and fire control system so accurate that the first few rounds of any attack would result in a sure kill. We have analyzed a weapons system of this type, allowing a reasonable evaluation of the system capability and comparing it with World War II capability. Believe it or not, it can be demonstrated that under certain circumstances, the probability of getting a kill for a given dollar expenditure is lower for the fancy, very expensive system with radar control than it is for a system where those same dollars appear as additional weapons. Like comparisons are being made between expensive guided missiles and conventional artillery for air defense or tactical support. This is just another example of the sort of support our Research and Development Program receives from our higher educational institutions. It will be our continuing effort to use these resources in every way we possibly can.

Academic Resources Effectively Employed

There are many other ways in which academic resources can be effectively employed to assist the Research and Development Program. The Army has just recently decided to increase the scope of the operations of the Control Systems Laboratory at the University of Illinois where work is being carried out under an Army administered contract for the Army, Navy and Air Force. Here we are establishing a level of effort by stating the number of dollars per month we are prepared to apply—thus effectively establishing a laboratory of a certain size. We direct the technical effort with a committee of representatives of the three Services approving tasks for the laboratory as new ideas are evolved. This gives us a very flexible means of enlisting the support of these scientists. When an idea reaches the prototype stage, it can be removed and given by contract to an industrial concern, thus keeping the scientists busy with more fundamental problems, and using industry for the more prosaic problems of straight engineering.

Another use for academic assistance is in the Army-Navy-Air Force supported contract at the Massachusetts Institute of Technology where an Air Force administered contract is seeking to solve major problems in air defense. Here, also, a high degree of flexibility has been retained in the contract. Major shifts of direction and emphasis can be made without rewriting the basic contract.

In addition to research leading to equipment or techniques for using equipment,

the Army is also supporting basic research. Although I personally have never actively been involved in basic research, and as an engineer by training my inclination is to concentrate on getting practical results, my experience with the Atomic Bomb Project has made me realize the significance of carrying on basic research. Although the atomic bomb is perhaps the classic example of a formidable weapon springing suddenly from basic research, many other lesser examples could of course be given. As engineers we certainly all must realize that the progress in applied research and applied engineering is always dependent on building a broad foundation of basic research.

The military also recognizes the value of basic research and the Army has established a bsaic research committee at the General Staff level to foster basic research on all the Technical Services. In addition, the Office of Ordnance Research at Durham, North Carolina, was established to fill the ever-increasing need of Army Ordnance for the fruits of technical research. The Office of Ordnance Research sponsors basic research in those technical areas that have proven valuable to Ordnance in the past or that promise to be similarly valuable in the future. This work is carried out almost entirely by small contracts with educational institutions. The primary requisite of these contracts is the availability of an able scientific leader who can direct and control the work. We hope that every effort can be made to give full freedom to the technical personnel not only in selecting the areas in which they will work but in deciding ways and means and the scale of effort in investigating those areas. The Office of Ordnance Research is quite young, having been officially established only about one year. I am certain that as it matures it will become one of the Ordnance's most valued assets.

In the utilization of university scientists we still have many problems to solve. We fully recognize that the military utilization of university talent can not be permitted to unduly interfere with the education of future scientists and technicians. Moreover, we have no desire to eliminate the free-thinking in universities for it is this very free-thinking—or free-wheeling as it is sometimes called—that is one of the intrinsic values of university research. It is particularly of value when one recognizes that the very nature of government red tape tends to make government laboratories more conservative in their approach to solving problems. We need both approaches.

Contracting Procedures

In addition to worrying about the impact on the basic mission of universities, we in the military also have a long way to go toward arriving at acceptable contracting procedures and methods of coordinating the division of effort between various universities and industrial contractors so as not to create unnecessary friction and useless effort. For a good many years I have been exposed to the task of trying to coordinate the efforts of military, industry of various types, universities, labor unions, and in some cases plain ordinary housewives at isolated locations, and I can only say that to get any harmony at all out of these diverse groups requires a recognition that we are all different breeds of cats and must be handled accordingly. Perhaps some day we will develop a breed of military cat that knows how to handle such problems—certainly that is a task facing the Army today. So to those of you who have government contracts, all I can ask is your patience in bearing with us while we all learn to appreciate each other's talents and shortcomings. One of the worries that has repeatedly raised itself in the Research and Development Board is whether the continued expansion of the military Research and Development Program can be supported by the universities. We recognize that we are constantly diverting a greater and greater proportion of university talent to our military effort. Certainly a study of the record indicates a tremendous growth in military research. A review of the rec-

ords for the past 12 years indicates that the Army Research and Development Program has expanded some 20 times as compared to immediately before World War II. It is more than twice as large as our peak during World War II, and is some four times as large as the period immediately after the war when we were all more hopeful for a long period of peace.

Expand or Stabilize?

One of the real questions facing us is —can we continue to expand or have we reached a point where we should stabilize our effort? Certainly the problems confronting us all point to the desirability of an increased effort, but should we continue to increase this effort if the long term effect on our educational institutions is too serious. If we are faced with immediate all-out war the answer of course is more obvious, but we all hope that the result of our efforts in research and development and our armament program in general will be to reach a state where we not only can win a war if it is thrust upon us, but also that we may have the possibility of deterring war. Whether this effort will be a long one or a short one is very difficult to evaluate at this time. Certainly it must be weighed from year to year, and perhaps if we can utilize our funds and talent efficiently we can not only get the answer concerning the time and the degree of effort but we may also accomplish the major objective of avoiding war.

New ECRC Secretary

Virgil E. Neilly, Assistant Professor of Engineering Extension at the Pennsylvania State College, has been appointed Secretary of the Engineering College Research Council.

Professor Neilly, a graduate of the Electrical Engineering Department at Penn State, is a member of the American Society for Engineering Education and an associate member of the American Institute of Electrical Engineers. He has been honored by election to Phi Eta Sigma, Eta Kappa Nu, and Tau Beta Pi.

Professor Neilly's appointment was announced by Dean Eric A. Walker of the School of Engineering at Pennsylvania State College, who is Chairman of the Research Council. As Secretary, Professor Neilly succeeds John I. Mattill, now Director of Publications at the Massachusetts Institute of Technology.

The Engineering College Research Council, a unit of the American Society for Engineering Education, represents the research activities of ninety-eight leading engineering schools in the United States.

Should Engineering Schools Teach Engineering?

By THOMAS K. SHERWOOD *

Dean Emeritus, Massachusetts Institute of Technology

Engineering is sometimes thought of by educators as a collection of academic subjects constituting a curriculum. Others think of engineering as a way of life. Engineers are not walking encyclopedia, but men who do things. They are creators, designers, and managers, whose satisfaction in life comes from creative accomplishment. This is recognized by our form of engineering education, which is based on the principle of "learning by doing." Nevertheless, the engineering curriculum is designed primarily to teach men what they need to know *in order to start learning* something about engineering. It is really a pre-engineering curriculum.

It would seem that the basic tools of the practising engineer are five in number: concepts, principles, techniques, facts, and judgment. We teach the first four in formal classes, and hope that the student may acquire the fifth. The concepts include such things as temperature, heat, vapor pressure, and reversibility, which help an engineer to understand and to think. Principles include the chemical laws of combining weights, the first and second laws of thermodynamics, and Newton's laws of motion. Techniques include not only laboratory and industrial methods, but the technique of tackling a design problem, the use of the library, and the preparation of a good written report. The engineer must have a limited number of facts in his tool kit, but the straight learning of facts has always been emphasized less in engineering than in other curricula, and the last twenty years have seen a steady strengthening of the basic science at the expense of the empirical know-how or "handbook engineering" within the four-year curricula. But we have restricted our teaching primarily to the tools of the profession, and done little to introduce the student to the application of the engineering method to complex engineering situations. Referring to a similar list of "tools," the 1944 Report on Engineering Education after the War (3) states that "knowledge of these tools does not constitute ability to practice engineering."

The "engineering method" is more than a catch phrase. It involves the evaluation of a situation—a process seldom required in the solution of a typical ten-line problem assignment. It involves the selection of the appropriate tools—those applicable to the assigned home problem or quiz are usually indicated, or obvious from the context of the course. Very often it requires economic balances of a type which the student meets only in the most elementary form as an undergraduate. It usually involves the handling of situations without adequate data and without unique answers, in which conclusions based on judgment must be made and defended. These are so foreign to undergraduate instruction that students feel ill-treated when sometimes given an assignment with missing data, or one without a definite answer. These protected students experience a rude awakening in the cold world of engineering practice.

Examples

There are, of course, many examples of comprehensive design projects and other

* Professor of Chemical Engineering; Dean of Engineering, 1946–52.

techniques whereby the undergraduate is required to employ the engineering method in attacking real engineering problems, under the guidance of experienced teachers. Most such activities, however, are limited to a few undergraduates and the majority of the engineering students are not influenced.

M.I.T. chemical engineers engage in a comprehensive plant design problem, requiring cost studies and complete process engineering calculations for a chemical plant. But this is a graduate course. Last year seniors in electrical engineering tackled the design and promotion of a gas-discharge flash light for amateur photographers. This involved technical design, the question of the appearance of the product, a market study, questions of manufacture, financing, and advertising. But this was an elective taken by a few seniors. In mechanical engineering seven seniors did a group thesis on the improvement of a commercial vacuum cleaner. New fan blades and other parts were designed, produced by the manufacturers, tested and reported by the students. But we cannot get the technical assistance and several thousand dollars cash to support the theses of every seven seniors. At M.I.T. students get one of the finest of educational experiences in the Servomechanisms and the Instrumentation laboratories in working with creative teachers in the design and actual production of new mechanisms such as the Brookhaven pile's servo-operated control rods. But these again are graduate students.

One of the most intriguing possibilities along these lines is the plant design project engaged in by seniors from several engineering departments. Each group presents and defends its contribution to the complete project. In addition to the engineering experience, the student has the opportunity, rare to undergraduates, of learning to work as a member of a group. It is not known that this type of project is being carried out at the undergraduate level.

Educational experiences such as these, often available at the graduate but so seldom at the undergraduate level, represent the experience in *synthesis* for which purpose the four-year training in *analysis* is planned. But of greatest importance is the point that here is the opportunity for the engineering student, while still in college, to get some concept of the thrill of creative accomplishment, without which the college experience means little more than a four-year extension of the high school pattern. Where else will the student get an appreciation of the meaning of creative professional activity? In freshman physics? In applied mechanics? In courses in materials? Perhaps in a two-afternoon-a-week thesis in the second term of the senior year?

Our friends in architecture follow the project pattern, starting with second-year design. Somehow they are able to resist the temptation to require more and more subjects; a considerable fraction of the entire curriculum is devoted to design. Dean Hollister (1) has previously suggested that we may benefit from the example of the teaching of architecture. The 1944 Report (3) also refers to the system followed in architecture.

Objections Raised

Whether or not the comprehensive design project or other techniques of teaching the engineering method belong in the undergraduate program is certainly open to question. The 1944 Report gives one opinion—"Judgment matures only through experience, but introduction to the art of engineering and the development of judgment—in other words, elementary competence in the engineering method—can and should begin in college" (3). Many may argue that comprehensive exercises in the engineering method do not belong in the schools—that engineering schools should teach the tools of engineering but not attempt to teach engineering. I do not agree with this latter point of view, though I accept the fact that some will hold to it on principle. More, however, will conclude

that the objective is sound, but that such activities on any important scale are quite impractical within the limitations of the four-year undergraduate curriculum. The late President Wickenden wrote in 1929 that the limited treatment of creative engineering was "regrettable but inevitable" (2). The practical objections hinge on (a) the lack of qualified teachers for such an admittedly difficult task, and (b) the lack of time in a crowded curriculum.

I am not so sure the objectors are right on the first point. If the initial goal were to provide the equivalent of one full semester of the comprehensive project type of education, only approximately one-quarter of the instruction given by engineering department staffs would be involved. If a few imaginative teachers showed the way to the development of this kind of teaching, many others could follow their lead. Engineering faculties now include hundreds of men who have had wide engineering experience at a responsible level in industry, and many of these would follow such leadership with understanding and enthusiasm. Perhaps we could attract more such engineers into the teaching profession if our instructional pattern were not so completely compartmentalized into separate subjects, separated by artificial walls non-existent in engineering practice.

The second practical objection assumes that within the four-year curriculum there is now no material less important than the proposed project-type instruction in the engineering method—that it is certainly impossible to cut present material by the equivalent of one full semester. This is debatable—in fact it has been debated extensively in connection with the efforts in recent years to allot more time to the Humanities. But there is a difficult though possible way out—involving the killing of two birds with one stone.

Courageous Experiments Are Called For

The way out of the difficulty is illustrated by a recent experiment at M.I.T. Undergraduates in aeronautical engineering were offered an entirely new type of instruction in the second of two semesters in engineering thermodynamics. They were asked to design an air-conditioning system for a jet aircraft. Just that. First they had to learn something about jet aircraft, but they already knew a little. Why air-conditioning—for the equipment or the pilot? How much would the cooling load be? Why did it get hot? These questions led to a study of heat transfer, then concepts and theories of stagnation temperatures, a realization of the inadequate state of the art as revealed by the literature, and finally into problems of refrigeration engineering. At the end of the semester these students took the same final exam as those students who had taken the regular course in thermodynamics, and did as well. In other words, it *is possible to provide the creative engineering-project type of instruction without sacrificing the haloed "coverage" of "material" to any important degree.*

The idea of comprehensive projects and other schemes for instruction in the engineering method is certainly not novel. Both the 1940 and the 1944 Reports list this as one of the main objectives of the scientific-technological stem of the curriculum, and describe this objective in specific terms. The 1944 Report describes a course or subject designed with this particular objective in mind. It would seem, however, that too little has been done, and that the experiments have been on too small a scale. The objective cannot be attained by changing the instruction within the framework of discrete subjects, either by modifying existing subjects or by single new subjects. Really worthwhile results will be obtained only by the imaginative use of large blocks of student time, of the order of entire semesters.

To do much of this sort of thing is clearly a large order. But engineering education is in something of a rut, and courageous experiments are called for.

Except for the great strengthening of our programs through the application of more science and mathematics, there has been little fundamental change in two generations. The curriculum is still four years (with few exceptions) following high school; it is still made up of poorly-related separate subjects; and the subjects are mostly the same subjects, modernized, but taught in much the same way. The idea that engineering schools might also teach engineering suggests the challenge of a departure from tradition which, at the very least, would provide the student motivation so often lacking.

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College Notes

Dean S. S. Steinberg of the **University of Maryland** College of Engineering has been named adviser to the School of Engineering of the University of Puerto Rico at Mayaguez. He plans to visit the island commonwealth early in March to confer with university administrative officers and faculty members on the development of their engineering curricula and laboratory facilities.

* * *

The largest group of Special Summer Programs in the history of the **Massachusetts Institute of Technology** will be given at the Institute next summer. These special programs, designed for professional personnel from industry, government and educational institutions, will be given in addition to academic subjects from the Institute's regular courses and in addition to several technical conferences which have been planned in a number of fields.

* * *

A bequest of the late Norman W. Church of Los Angeles to the California Institute of Technology, together with gifts he made to the Institute a few months before his death January 7, will make possible construction in the near future of a $1,500,000 laboratory for education and research in the field of chemical biology. The laboratory is to be known as the Norman W. Church Laboratory of Chemical Biology. It will be joined to the present Crellin Laboratory of Chemistry and also eventually to the Kerckhoff Laboratories of the Biological Sciences.

* * *

Cooperative programs enabling a student to obtain degrees in both liberal arts and engineering have been arranged by **Stanford, Knox College,** and **The College of Idaho.** Selected students at Knox and Idaho will take a three-year liberal arts course at their college, followed by two years of specialized training at the Stanford School of Engineering. Upon successful completion of the five-year course, the students will be awarded a bachelor of arts degree by their college and a bachelor of science degree by Stanford.

Isn't This the Crying Need?

By WILLIAM W. ROGERS

Head, Dept. of Mechanical Technology, Long Island Agricultural & Technical Institute

Almost daily we read in our newspapers, magazines, and technical publications, hear on radio, and watch speakers on television all publicizing the great need for engineers. Occasionally, the great need is questioned, as in Time Magazine of April 21, 1952 a spokesman for the U. S. Steel Company reported that 75% of the jobs for which engineers were hired could be filled by graduates with B. A. degrees. The magic figure "80,000 engineers" is never accompanied by an equally important quota, of let us say, "400,000 technicians," and "1,000,000 semi-skilled industrial workers."

Just as surely as the low birthrate of the 1930's cannot be altered, the heavy demands of the military program ignored, and bad advice (about five years ago) to guidance counselors be recanted, we as educators for industry are doing collectively little to put forth a broad program to obtain students in training for all branches of industry. Some militant leadership is needed in our field. It is needed to assemble the forces of engineering, technical, and vocational education at all levels, into a solid group to develop a program to provide our future students.

Today we have no such comprehensive program. In the *Journal of Engineering Education,* September, 1951, Dean Hollister of Cornell University said, "The educational system that has come into being in this country certainly was not evolved after a preconceived national plan, as far as engineering and allied schools are concerned. Whereas abroad there is commonly a technical institute functioning in parallel with strong professional engineering education, there have been relatively few technical institutes in this country, leaving the burden of serving both needs upon the engineering schools." The relatively few technical institutes in New York State have met the same avalanche of personnel recruitment men as have engineering schools. Studies * have shown that for each engineering position there is need for four to twenty technicians.

We need a program that will fill our schools with students for all levels of industrial competency. Our present efforts (which center principally about the needs of the engineering school) only taps the surface. An overall program for students must go back farther than the high school, farther than the elementary school, and into the home. Through every communicative means it must be shown that a future in industry has respectability, profit, and great promise. No additional studies of needs are necessary; the Educational Policies Commission report,† Education for All American Youth is one which did the job well. What is needed is leadership. Consider the magnitude of the program of the National Safety Council; ours should be as broad and unceasing.

A strong program for industrial occupations would only strengthen the good elements in our present educational pat-

* Vocational Division Bulletin No. 228, Vocational-Technical Training for Industrial Occupations, U. S. Office of Education. (Superintendent of Documents, Washington, D. C. 40¢.)

† "Education for All American Youth," Educational Policies Commission, 1201 Sixteenth St., N. W., Washington 6, D. C. ($1.00).

tern at the elementary and high school levels. Well-educated high school graduates with a broad background in humanistic-socialistic studies, mathematics, and science, and an enthusiasm for technical work are desired in all levels of vocational, technical, and engineering positions.

The three principal fields of training for industry each work with industry but do not work together. Representatives of vocational and technical education meet together for mutual good as rarely as do the technical institutes and engineering schools. It would not serve our industrial needs at all to assume that one type of school should serve as a preparatory ground for another; there are fixed ratios of needs of engineers; technicians; semi-skilled workers which must still be met.

Let us be sure of this—there are great needs at all levels of industrial competency, and they cannot be met by meeting only the quota of engineers. Consider the case of those who enter industry with only two years of engineering education. Of one group studied,‡ about 70% stated positively that they felt that *lack of an engineering degree was no hindrance to success.* Again, from the April 21, 1952 issue of *Time Magazine,* "Today (the engineer) goes forth into a technician's world and an engineer's market." Technical schools can train its graduates to fill many positions for which engineering schools cannot. In many fields the technical institute graduate will be more successful, happier, and a better producer than the engineer. And until we resolve to approach our needs with an overall program, there will never be enough competent engineers, technicians, or semi-skilled industrial workers.

Our school population is growing at the elementary school level. Soon these students will be in high school and thinking of their future careers. By starting a campaign now, we can attain the future student body needed, and gather in many good students in the years before the large group born in the 1940's come into our technical and engineering schools.

What should be the principal elements of such a program? It should instill in the minds of young boys and their parents the concept that a future in industry is:

1. Financially rewarding
2. Respectable
3. Able to offer many unsurveyed horizons.

This we cannot do overnight; education is a process measured best by generations. Now is the time to plan for these generations. Now is the time to gather all resources. Now is the time to undertake a master plan for obtaining a student body in engineering and its allied branches—that will man our industrial enterprise today, tomorrow, and in the years we will never see.

‡ "Is Less Than Graduation Worthwhile?", Clement F. Freund, Dean, College of Engineering, University of Detroit, *Journal of Engineering Education,* September, 1951.

AMERICAN SOCIETY FOR ENGINEERING EDUCATION

NOMINATION BLANK

"ARTICLE XI, Section 3. (Election of Officers) By means of a form to be printed in The Journal of Engineering Education or in the preliminary program of the annual meeting, an opportunity shall be given to individual members of the Society to submit names of persons to be considered for said officers. These names, on the form provided, shall be sent to the Secretary of the Society not less than sixty (60) days prior to the annual meeting; and the Secretary shall submit the suggested names to all members of the Nominating Committee."

In order to make the election of officers of the Society as democratic as possible, members are urged to fill out the nomination form and return before April 1, 1953 to the Secretary, A. B. Bronwell, Northwestern University, Evanston, Illinois.

I nominate the following members of the Society for officers:

For President .....

.....

For Vice-President .....
(In Charge of General and Regional Activities—two years)

.....

For Treasurer .....

.....

Signed .....

Title .....

Institution .....

Date .....

The Co-op Prepares for Engineering*

By C. F. ARNOLD

Chief Engineer, Cadillac Motor Car Division, General Motors Corporation

My subject is "The Co-op Prepares for Engineering" and although these ideas will probably apply to other branches, they are based mainly upon my own experience as an *automotive* engineer.

My comments will cover: first, suggestions for classroom courses which should be given more emphasis; second, the main advantages which should be sought for in the shop periods; and last, some general comments on the advantages of cooperative education as it appears to me.

As to the courses which I think should be emphasized more strongly in the school portion of the course, it would be difficult to say which is most important but certainly the following group are near the top. One is applied mathematics. Far too many fellows leave school with the ability to solve differential equations but haven't the foggiest notion as to how they could be used to help themselves out of some practical problem—and this does not necessarily need be confined to the higher brackets of mathematics. We have a simple application of first degree simultaneous equations which enables us to determine the weights of the upper and lower end of a connecting rod much more simply than by the conventional weighing method.

Another is what we might call Dynamic Design—the mathematician would have a tough time justifying the modern crankshaft design, but it has developed along very sound principles For example, a great deal has been learned on handling or avoiding high stresses, which should be taught to the student.

Closely allied to this is the study of vibration Practically every part of an automobile is concerned with vibration in some way or another The crankshaft vibrates in bending and in torsion The entire power plant bends as a beam on its supports and can be excited resonantly at certain speeds. Example: We ran into this a number of years ago when we had a very hard to identify "boom" in the car at about 55 mph After a great deal of work, this was traced to a week flywheel bell housing which was permitting the entire power plant to flex in the middle It was excited by the propeller shaft and its natural frequency occurred at this 55 mph speed Once the cause was determined, it was fairly simple to stiffen the bell housing sufficiently to raise its natural frequency above the driving range of the car and thus eliminate the objectionable period. The propeller shaft must be very carefully designed to avoid critical periods and so on with the motor supports, the sheet metal reinforcements, the body mountings and the steering mechanism, to say nothing of the frame and suspension which are, of course, special problems in vibration dampening.

From my own experience, the study of metallurgy has probably been used more than any other course which I studied and a working knowledge and understanding of both the ferrous and nonferrous metals is more important today than ever. We should also include, and keep up-to-date, courses on the characteristics and uses of plastics, glasses, ceramics, rubber,

* Presented before the Co-operative Education Division of the A.S.E.E. at Michigan State College, Lansing, Michigan, June 27, 1951.

silicones and other new materials as they are made available for modern design.

Although I have not had the opportunity of checking this personally, I suspect that modern drafting room practice, as used in most plants today, is quite different from that which is taught in most schools and it might be well for the drafting instructor to periodically visit some of the more progressive design rooms in the industry to keep up-to-date on the constantly improving methods.

Sooner or later the successful man in any line needs training in effective speaking and I think that the earlier this is started the better, as it not only is helpful for public speaking but, to my mind, is a great deal *more* valuable in the day-to-day contacts in conferences and in the transmission of instructions to other members of the organization.

Some of the basic principles of human relations should most certainly be taught. I know of many very promising engineers, who were tops technically, that have failed to advance because of their ignorance of the importance of learning to get along with people. Every organization has its "problem children"—men who are extremely valuable in certain jobs but who must be handled carefully to keep them happy and with today's shortage of engineers, this is very important.

And last in this group, a knowledge of cost accounting is most important in today's economic race. The engineering designs must not only be good but they must be capable of being produced at a reasonable cost. The old wisecrack, that an engineer is a guy who can do for a dollar what any fool can do for two dollars, is certainly truer today than ever before.

Training in Industry

In the shop portion of the course, the co-op's program should be planned so that he covers everything from the simpliest type of work through to the most complicated operations. And he should be taught to try to obtain what we might call the shop atmosphere: the workmen's point of view and attitudes, their side of the labor question and their thinking on organized labor. He gets to see a side of the workmen which is rarely revealed to the graduate of a regular course even though he may be given shop trainee or apprentice courses. Starting as he does as a rank beginner, the co-op is taken in as one of them and does not meet the wall of difference which confronts the man who has taken a straight course and enters the shop as a "College Graduate."

The co-op should, if possible, obtain experience in all of the departments concerned in the manufacture of production automobiles: the foundry, machine shop, welding department, the press room, the plating department, and assembly work; he should have some inspection experience and then spent his last year in the engineering department. I realize that this much coverage is probably never obtained but it should certainly be the objective and if the total number of work weeks in the 5 or 6 years course is carefully divided and assigned, it should be possible to come close to this ideal.

Advantages

As to the general advantages of co-operative training, it certainly gives the man the opportunity to find out, at the earliest possible moment, whether or not he is really fitted to do what he thinks he wants to do. I talk to youngsters these days who have been over-impressed by the magic word "research" and picture themselves in a long smock, surrounded by electronic equipment and coils of blown glass, discovering some new form of energy; but soon quit and go home when they find out that they have to start helping somebody bolt together a base to support the stand on which some of this equipment is to be placed. Being able to get a taste of the kind of work which he has selected, while he is still able to change his course, is a tremendous advantage and I think your records will show that while the co-operative student may change from mechanical

to civil engineering or from chemical to metallurgical, once he graduates, he rarely changes his profession.

There is another intangible advantage in obtaining his shop work at the same time as his technical training, compared with the fellow who goes to school for 4 or 5 years straight and then goes out and gets experience. We might compare it to the advantage of intimately mixing the sand and cement before the mortar is prepared—it forms a bond which cannot be obtained in any other way.

Then there is, of course, the economic advantage of co-operative training. Many of us could not have obtained an education without the financial help which the work periods provide.

The co-op is much more likely to stick it out and finish his education than the student taking the straight course; seeing the alternative constantly before him in the shop, of men who have not trained themselves and are trying to advance without that distinct advantage, is one of the strongest incentives to complete his education. I know of many instances when men left a school period discouraged and ready to quit but returned from the shop period with renewed enthusiasm and a resolution to see it through.

Co-operative training gives a man a basic understanding and sympathy for the shop problems which he never forgets. In some plants there is downright enmity between manufacturing and engineering. The factory group thinks the engineers are a bunch of impractical, arbitrary, stuffed shirts who sit up in their tower and try to devise something more diabolically difficult to make, while the engineer looks down on the shop men as a bunch of uncivilized barbarians who never make anything like the drawings and then wonder why it won't work. Such attitudes are never found in co-operatively trained men, whether they wind up in manufacturing or engineering; they have a real respect for the other fellow and a sympathetic understanding of his problems and this is the only basis on which a continuing sound business can be built.

One of the turning points in my experience developed from such a contact. It was in 1938, we had just brought out a new V-16 engine and, while over in the shop, I noticed that a number of problems had arisen in its assembly. At the time, I was in charge of the dynamometer lab which had done much of the development on the engine, so I pitched in and spent several days in the shop explaining the new design and helping work out their problems. While there, the Works Manager and the General Manager stopped by and, as a direct result of this, when the new job of Production Engineer was established I was given the assignment. Perhaps any man would have done the same under the circumstances but for the co-op it was a natural reaction.

Co-operative training also gives him an appreciation of the serviceman's problems and of the importance of designing for accessibility and easy repair.

Need for broad knowledge

The young engineer should be sold on the value of continually broadening his knowledge. I am frequently asked by members of our organization "How can I get ahead?"—"What should I do to get a promotion?" Of course no two cases are exactly alike but in almost every instance I find that the following suggestions apply. Lets' take the job of Laboratory Supervisor as an example. It is assumed that we have several candidates, all ambitious, all having some leadership ability and having good technical training. If all of these characteristics were equal, the job would not necessarily be given to the best dynamometer operator but to the man who has best informed himself on all phases of testing. The Staff Engineer on chassis may not be the best specialist on brakes, or axles, or transmissions, but the man who knows most about *all* of them. In this day of specialization, it is easy for a man to get into a rut but that applies to his coworkers just as well and if he will take the trouble to learn something of the

other fellow's "rut," while doing well his own job, he will stand up head and shoulders above his competitors when the choice is made for a promotion. Just take the top job in any industrial organization—the General Manager—the first word of his title tells you what his responsibilities are. He must know Sales, Manufacturing, Purchasing, Engineering, Accounting and Personnel handling—but few men ever go through all these departments in their normal career. After the man became head of one of these groups, he was selected as General Manager because he, in addition to knowing his own job, had learned more about the others than anyone else, and that principle applies right down to the foreman of the smallest department.

This is good advice for any man on the way up, but for the co-op, with his basically broader background and training, it is a natural—and, aggressively used, is a success formula which I have never seen fail to get results.

Conclusion

So, as the co-op prepares for engineering, give him more courses which he can apply directly in his work, encourage him to get the full benefit of the "shop atmosphere" during his work periods and impress upon him the importance of continuing to expand the broad start which you have given him in his education, for, like a pyramid, a big man needs a broad base.

College Notes

The **University of Wisconsin's** new Chemical Engineering Building is gradually being put into full use on the UW campus as installation of its technical equipment is completed in its 10 laboratories. The building has three stories and basement constructed of concrete, lannon stone, and brick, and besides the 10 laboratories, it provides classrooms and offices and other special service and work rooms for the University's chemical engineering staff and students.

* * *

The Division of Applied Science of **Harvard University** announces the appointment of Dr. John H. Curtiss and Dr. Andre Guinier as Visiting Lecturers for the spring term of the academic year 1952–53. Dr. Curtiss is Director and Founder of the Institute of Numerical Analysis of the National Bureau of Standards. He is also a member of the National Research Council Committee on High Speed Computing Machines. He will give a course concerned with problems of numerical analysis. Dr. Guinier is Professor at the Sorbonne, and is internationally known for his work in the field of x-rays and metallurgy. His research laboratory is located at the Conservatoire National des Arts et Metiers in Paris. His lecture course at Harvard will be on the subject of x-ray metallography.

A Simplified Technique for Item Analysis*

By R. O. SWALM

Associate Professor of Industrial Engineering, Syracuse University

Introduction

The making of good tests is not an easy task—and after attempting to construct a good test a teacher naturally wishes to measure the success of his efforts and perhaps to build up a file of good test items. One of the techniques available to him is an item analysis to determine which item proved most useful in that particular test.

In this paper the scope and theory of item analysis will be discussed very briefly and then a simplified technique for item analysis will be presented. Finally a few brief remarks concerning the use of this technique will be made.

Item Analysis

Before anything can be evaluated, a standard against which it is to be measured must be established. In judging the effectiveness of various test items, two guiding principles will be used. The first of these is that, in order to most effectively differentiate between abilities throughout their entire range, items should range in difficulty from very easy to very difficult —ideally, at approximately equal increments of difficulty. The second is that each item should be useful in selecting superior from inferior ability in the field being measured.

Unfortunately, the implications of the first principle are denied, in practice, by a great many engineering instructors. The objective of too many teachers seems to be to make all items on a given test of equal difficulty, and generally with the expectation that the great majority of the class will answer between 55 and 95% of the items correctly.

Since it is extremely rare for a test to have an error of measurement of less than ± 10 percentage points (generally it is much higher than this) it should be obvious that there will be relatively few instances in which we can say that, based on the evidence offered by the test, one particular student is definitely superior to another. Certainly the probability of a man who obtained 85% being actually superior to another who obtained 75% is slight—and the probability of the reverse being true is far from zero.

How can this uncertainty be overcome? By deliberately setting out to spread the grades of the same group from about 10% to 90%! This will have an effect comparable to that obtained by using an air gauge instead of a scale to measure the diameter of a shaft. By so doing, we do not change the thing being measured (in this case a shaft), we do not change the *actual* error of measurement introduced by the human eye (on the air gage as on the scale, we can detect a difference of about one one-hundredth of an inch on the scale being read), but we will expand a small range of sizes to a large physical range on the air gage so that the error of measurement introduced by the eye is relatively less important.

In testing, it has been found that, by submitting items that range from the very simple to the extremely difficult, we can expand the range of percentage grades, that, under the traditional methods, would vary from 55% to 95% to the point

* Presented before the Educational Methods Division at the Annual Meeting of the ASEE, Dartmouth College, June, 1952.

where they vary from, say, 10% to 90%. This will have little effect on the error of measurement, so that the precision with which we can rank students is greatly increased. If our error of measurement is ± 10%, we are quite confident that a student who obtains 75% is definitely superior to one who obtains 50%. Of course, this means that we will have to use different standards in translating from numerical to letter grades—but to say that 50% is equivalent to a grade of "C" is certainly no less arbitrary (though perhaps less traditional) than to say that 75% is equivalent to "C". It requires some re-orientation in the thinking of both faculty and students—but as engineers we should surely be willing to re-orient our thinking in order to gain greater precision at no increase in cost.[1]

With regard to the principle that each item in a test should be useful in selecting superior from inferior ability, the obvious difficulty in determining the degree to which this objective has been met is the selection of a suitable criterion.

Unfortunately, knowledge of the relative ability of students is seldom present. Indeed, if it were, there would be little purpose in giving a test. This is not an insurmountable difficulty, however, for if it is assumed that the test as a whole is a valid instrument, each item can be measured against the whole test. This assumption will probably be reasonably accurate if the test maker has critically asked himself, "Does this test measure what it purports to measure? What am I trying to test for—knowledge of facts? Understanding of facts? Ability to apply principles in new situations? etc.," and then, "Does this test measure these abilities?"

In measuring each item against the whole test, the basic criterion may be stated as "As compared to those who do poorly on the test, do a significantly greater number of students who do well, answer this item correctly?" If they do, the item would appear to make a positive contribution to the whole test. If, on the contrary, more inferior than superior students choose the correct answer, the item is probably not useful in its present form. A danger signal has been raised—the item should be investigated. Further, if only a few more of the better students answer an item correctly, this may be attributable to chance and the item probably does not discriminate well between various levels of ability.

If the test maker is attempting to measure several different abilities, it should be recognized that he is in reality giving several different tests. Unless the correlation between these several abilities is very high (and it frequently is not) items in each of these different tests should ideally be evaluated against scores on that test alone.

The most useful measure of an item's ability to discriminate between different levels of achievement is the co-efficient of discrimination. There are several types of such co-efficients; one of the more useful bears the imposing name of "Tetrachoric," and this particular measure of discriminating ability will be used herein. Unfortunately, like the others, it is not simple to compute. Charts are available to simplify the work required, but even with these it is necessary to divide the test papers into halves, one containing the higher and the other the lower scores. Then the per cent of the students in each half who respond correctly to each item to be analyzed must be computed, the chart entered with these values, and the value of the coefficient of correlation read (frequently by performing graphical interpolation). This is laborious and still does not answer the question, "How large should this co-efficient be to be significant?"

For practical use, the teacher is not concerned with the actual value of this co-efficient—he need only know that it is high enough to be significant, or to indi-

[1] For a more complete discussion of the logic behind this concept, the reader is referred to an excellent exposition in Chapter II of Hawks, Lindquist, and Mann's "Construction and Use of Achievement Examinations," published by Houghton Mifflin.

cate excellent discrimination. If such information can be obtained with little effort, it will be used far more frequently than an exact value that can be obtained only with relatively great effort. It therefore seems worthwhile to propose a simple method which can be used to select items which have a high probability of showing good (or excellent) discrimination in future tests. This method will *not* offer proof that the remaining items should be discarded. This is impossible, both from a logical and a statistical standpoint. Careful consideration of such items before their re-use, however, is definitely indicated.

Development of the Proposed Technique

Families of curves showing the value of the tetrachoric co-efficient or correlation as a function of the per cent of students in the upper half who answer an item correctly (Pu) and the per cent of students in the lower half of the class answering the same item correctly (Pl) have been developed by Mosier and McQuitty [2] and improved by Adkins.[3]

These curves are plotted letting the ordinate represent the percentage of the upper 50% passing an item and the abscissa the percentage of the lower 50% passing the item, each increasing from 0 to 100%. The curve corresponding to $r = 0.00$ is the diagonal passing through the origin; all curves representing positive values of r are above this line, symetrical about the other diagonal, and increasing in curvature and in the distance of their midpoints (falling along the second diagonal) from the midpoint of the curve for $r = 0.00$ (as r approaches 1 the curves approach co-incidence with the left and upper sides of the square making up the chart). If, on the curve for any value of r, a tangent is drawn to it at 45° to the horizontal, the equation of this line will be in the form $Pu = Pl + Cr$ where Cr is the point where this line intersects the ordinate.

Rewriting this equation as $Pu - Pl = Cr$ and remembering the straight line described by this equation is at no point *lower* than its corresponding curve for r, it is obvious that if $Pu - Pl$ is equal to or greater than Cr, the corresponding value of the tetrachoric correlation co-efficient must be greater than the value of r.

Obviously the value of Cr will be a function of r, and this function can be determined empirically.

Better still, the data can be transformed into equations involving the actual number of students (N), the number in the upper group (U) (as measured by the whole test) who answered the item correctly, and the number in the lower group (L) answering the item correctly. These equations are of the form $U\text{-}L = Kr \times N$, where $Kr = f(R)$ determined empirically.

The remaining problem consists of determining appropriate values of r (and therefore Kr) as criteria of the discriminating ability of an item.

These criteria were chosen by arbitrarily defining the discriminating power of an item as good when it was significantly greater (at the 2 sigma level) than 0.1; as excellent when it was significantly greater (at the 2 sigma level) than 0.3.

Since the value of the standard deviation of the tetrachoric co-efficient of correlation is known,[4] and is a function of the value of r and the number of observations in the sample, critical values of $U\text{-}L$ for the desired criteria are readily obtainable as a function of N. These

[2] Mosier, Charles I. and McQuitty, John V., "Methods of Item Validation and Abacus for Item Test Correlation and Critical Ratio of Upper-Lower Difference." *Psychometrica*, Vol. 5, No. 1, March 1940, pp. 57–65.

[3] Atkins, Dorothy, "Construction and Analysis of Achievement Test," U. S. Government Printing Office, Washington, D. C., 1947.

[4] See Peters and Van Voorhes, "Statistical Procedures and Their Mathematical Bases," page 372, McGraw-Hill, 1940.

(a)	(b)	(c)	(d)	N	Min. Values for (d)		(e)	ITEM DIFFICULTY CHART
ITEM NO.	NUMBER GETTING ITEM CORRECT IN		(b) Minus	8-16 17-21 22-29	3 4 4	4 5 6	(b) Plus	CLASS LIMITS FOR (e)
	UPPER 50%	LOWER 50%	(c)	30-35 36-43 44-57	5 5 6	7 8 10	(c)	0 .2N .4N .6N .8N N
				58-70 71-82 83-104	7 8 9	12 13 15		0
				Poor	?	Good	Excellent	

ITEM ANALYSIS FORM

FIG. 1

were obtained using graphical methods, and the continuous curve obtained was transformed into the discrete values appearing on the proposed form.

Use of Proposed Form

In order to make the application of the technique developed as simple as possible, the form shown as Fig. 1 was developed. While a description of the use of this form is necessarily somewhat involved, its actual use will be found to be quite simple.

The following instructions for use of this form have the virtue of completeness if not that of brevity:

1. Score the test papers in the usual manner.
   a. All correctly answered items must be clearly marked right and/or all incorrectly answered items clearly marked wrong.
2. Divide the test papers into an upper half and a lower half on the basis of their total scores.
   a. If there are an uneven number of papers, omit the median paper.
   b. If the median score appears on several papers, assign one half of these at random to the upper group and the other half to the lower group.
3. Fill out columns (b) and (c) on the form by tallying the *correct* answers on each successive paper; first for the upper group and then for the lower group.
4. For each item, enter in column (d) the difference between those in the upper half getting the item correct and those in the lower half getting the item correct (column (b)—column (c)).

   Note that some of these results may be *negative.*
5. In the column headed "Minimum values for (d)" circle the number corresponding to the total number of tests. (For example, if there were 33 tests, 5 and 7 would be circled.)
6. If the value for an item shown in column d is negative, place an x in the

column headed "poor"; if the value is positive but less than the value circled above "good" place an x in the column headed (?); if the value is as great as the value circled above "good" but less than the value circled about "excellent" place an x in the column headed "good"; if the value is as great as or greater than the value circled above "excellent," place an x in the column headed "excellent."

7. In analyzing the results shown by this form, items marked x under "poor" are probably poor; those with x under (?) are dubious; those with x under "good" probably show good discriminating ability, and those with an x under "excellent" are those rare items which almost certainly discriminate well between superior and inferior abilities.

8. To obtain a rough item difficulty analysis, the total number of correct responses for each item (obtainable by adding the values shown in column (b) and column (c)) should be entered in column (e). Class limits for each 20 percentile range of item difficulty are obtained by entering the values for 0.2, 0.4, 0.6, 0.8 and 1.0 times N in the appropriate spaces.

9. For each item a check should then be placed in the item difficulty chart in the column bounded by the correct class limits.

10. The number of checks in each column should be totalled; ideally, these should be the ratio of 1:2:2:2:1 reading across the page. Any marked deviation from this ideal serves to indicate the direction of potential improvement of subsequent similar tests.

Limitations of the Proposed Form

There are two types of limitations to be recognized in using this proposed method for evaluating items. The first are those intrinsic in the basic theory, the second, those imposed by the approximations employed in this method. The first can well be sumarized in the quotations from Hawkes, Lindquist, and Mann's "Construction and Use of Achievement Examinations" which follow:

". . . to use the total score on *the test itself* as the criterion against which the constituent items are evaluated only enables one to select those items in a test that are individually most effective in measuring whatever the test as a whole is measuring. If the test as a whole is not valid, if it happens to be measuring the wrong thing, then the selection or elimination of items on this basis would only make the revised test a more reliable measure of the wrong thing; i.e., the test would become more reliable as it becomes less valid. . . . An index of discrimination, therefore, should be used with particular caution . . . where the criterion employed is the total score on the test itself. It may be of considerable value, in such situations, in identifying items that contain structural or technical imperfections, but it is a dangerous basis upon which to eliminate an item if the content of that item is acceptable in terms of other logical considerations" (pages 51, 52).

". . . it should be noted that the numerical value of the index of discrimination is not directly proportional to the desirability of an item for inclusion in a general achievement test. . . . In general, the best procedure seems to be to use the index of discrimination solely as a means of identifying seriously defective items, i.e., those with negative or very low indices, but not to employ it as a means of choosing between items showing reasonably high positive indices—the choice in the latter case to be based primarily upon logical rather than statistical consideration" (page 54).

The chief limitations imposed by the approximations used are:

1. As in any method based on significant differences, the results of this technique will enable the user only to state that certain items show a significantly good or excellent discriminating ability. Many of the remaining items might, if a larger sample were available, also prove to have good discriminating ability—but

this cannot be known unless more data are available.

2. The approximations on which the tests for discriminating ability have been designed are on a "fail-safe" basis. Stated another way, the criteria selected are, in many cases, more severe than would be demanded by more laborious exact methods. They are never less severe. These criteria are particularly severe from those items which are answered correctly by

a. 90% or more of the upper group
b. 10% or less of the lower group

3. The item difficulty analysis gives only a rough picture of the range of difficulty of test items. If there is a marked preponderance of checks in one or two of the columns, future attention should be given to writing items that will fall in the other ranges if a test is desired that will discriminate well between all levels of ability.

In the News

Thomas H. Chilton, Technical Director, Engineering Department of E. I. du Pont de Nemours & Company, has been named new Chairman of the Engineering Manpower Commission of **Engineers' Joint Council.** Formerly serving as President of the American Institute of Chemical Engineers in 1951 and then as Vice President of Engineers' Joint Council in 1925, Dr. Chilton has been active in the profession since graduating from college. Dr. Chilton graduated as a Chemical Engineer from Columbia University in 1922 and, after working in research, joined the E. I. du Pont de Nemours & Company in 1925 where he rose through the ranks to his present post.

Reginald James Seymour Pigott has been elected President of the **Engineers' Joint Council.** Mr. Pigott, former President of The American Society of Mechanical Engineers who is presently a consultant to the Gulf Research and Development Company, was recently retired as Chief Engineer, Director of Engineering Division, Gulf Research and Development Company in charge of engineering research. He graduated from Columbia University with a degree in Mechanical Engineering in 1906, returning a few years later to teach as professor of steam engineering.

Where Is the Challenge?

By J. F. LEE

Associate Professor of Mechanical Engineering, University of Maine *

The increasing loss of promising or clearly established engineering educators to permanent positions in industry represents a trend with grave implications for the future of engineering education. Replacements of equal capability are becoming progressively more difficult to find, and there is, of course, little assurance that the replacements themselves will remain in the profession for long. Since this condition appears to be widespread, it is worthy of the most critical examination. Should the trend continue or take a turn for the worse, it is apparent that eventually there will be a general dilution of the quality of engineering instruction. The difference which exists between academic and industrial salaries is blamed entirely by the casual observer who resigns himself to a situation for which little relief can be forthcoming in the foreseeable future. However, a more studied observation reveals that far more compelling factors than that of salary alone are involved in the ultimate decision of the engineering educator to leave the teaching profession.

Views of Former Educators

Beyond doubt, a great deal can be done outside of salary matters to provide a solution to this most real and serious problem in the opinion of engineering educators from various parts of the country who had recently left the teaching profession. Without exception, the former engineering educators interviewed readily admitted they had entered engineering education with the full expectation that the salary scale would be lower than that of industry. Some had even left industry for lower paying teaching positions. But they had expected teaching to offer advantages outweighing the financial considerations. Clearly then, something had happened in these cases to disturb the balance. Further examination revealed that in most instances the fault could be found in the complete or partial failure of the profession to provide the expected advantages. What advantages these men expected but did not find can be generalized by the following statement. Engineering teaching was expected to be an exciting and challenging experience providing a genuine feeling of accomplishment, requiring responsible decisions, and affording ample time and opportunity for professional development. Instead, engineering teaching was found to be a dull and slavish routine, stifling to the imagination and equally frustrating to creative ambitions, devoid of serious responsibility, and, in the final analysis, leaving nothing to the individual teacher but a feeling of growing incompetence as an engineer. It should be emphasized that the two preceding statements represent a composite view of the group interviewed. Nevertheless, enough of the elements were evident in any single case to make the statements fairly characteristic. One must agree that what was expected of the profession was reasonable and indeed desirable. Certainly engineering teaching has the inherent capacity to fulfill all that was expected of it by these former teachers.

Much was said by the people interviewed about the need for time and op-

* Now at North Carolina State College, Raleigh, N. C.

portunity for professional development. Therefore, it appears appropriate to review in what ways it was expected that professional growth could be attained. The means selected varied widely among the persons interviewed. Among those means stated were: research, keeping abreast of current developments in the field of major interest by extensive reading, part-time engineering practice, contributions to the professional journals, textbook writing, improvement of pedagogy, and participation in the activities of the professional societies. It will be recognized that all of these means provide tangible evidence of one's professional growth—a rather significant observation.

In seeking the causes for the disillusionment in engineering teaching, it becomes painfully evident that lack of responsibility and lack of time and opportunity for professional growth were the primary ones. All the disillusioning aspects of engineering teaching appeared to be either indirectly or directly traceable to these primary causes.

As for responsibility, it was felt that engineering teaching certainly did offer many responsibilities. The difficulty existed in the fact that the teacher was not permitted to assume responsibilities that are rightfully his. Often the individual teacher had no voice in formulating academic policy. In some instances, the curriculum and even the course contents were dictated by the department chairman without even so much as consulting the faculty concerned. Sometimes teachers were arbitrarily assigned to teach courses without consideration for their interests and talents. In an extreme case a teacher might find himself assigned to teach a course in which he was not at all interested merely to plug a hole in the teaching schedule. Obviously, such practices cannot foster a feeling of responsibility on the part of the teacher.

Closely related to responsibility in engineering teaching is that of professional growth. Whatever the means selected for professional growth, it is evident that time is a condition precedent to its achievement. In this connection, the most roundly condemned detriment to professional growth is that of loading the teacher with an excessive teaching schedule both in point of hours, number of students and numbers of courses. This practice is objectionable because it leaves the teacher little or no time for professional development. Where excessively large classes are involved and no assistance provided, the routine chores incident to teaching absorb such a disproportionate amount of the teacher's time that the joy of the classroom experience is largely obscured. With time at such a premium, there appears to be a common tendency to neglect reappraisal of course objectives and for the course work itself to settle down to a lifeless routine. It is not too difficult to understand that under such conditions teaching becomes a dull and slavish routine stifling to the imagination.

Views of the Writer

Much can be done by engineering schools to reduce teaching loads even when financial conditions do not permit increasing the staff. This can be done by a critical examination of the entire curriculum with a view to eliminating some courses and consolidating others. This should be done with the attitude of increasing the quality of teaching at the expense of the quantity. Aside from the core curriculum, some courses are found in the curriculum only because tradition places them there. Perhaps these should be eliminated. Often a large number of elective courses are offered. Perhaps this is a luxury in which the institution is not financially equipped to indulge. Some courses overlap each other so that consolidation into a single course may be feasible. Again, a course may meet five times per week when the course objectives can be adequately met in three meetings per week. In some instances it may be entirely feasible to consolidate two or more divisions or sections of the same course into a single division. A part-time assistant could be provided to

reduce the burden of checking homework, etc. if the resulting division includes a great many students. Laboratory and shop courses should be carefully scrutinized. These courses represent a considerable investment in building, machinery, equipment, and materials which, many times, is inconsistent with the returns. This is particularly true of shop courses and to some extent laboratory courses where the object is to test heavy machinery.

The result of incorporating such changes would be a reduction in contact hours both for teacher and student. This reduction would be beneficial to both since the student would have more time to spend on the courses taken, and, similarly, the teacher would have more time to improve the quality of his teaching. With more time to spend on his courses, the student can be expected to show a higher standard of performance. Therefore, though the number of courses would be reduced, the quality of learning and teaching would be greatly improved. This would seem to be a much better investment of available funds and time.

With time available, most of the means to professional development may be pursued by the engineering staff. It would be a rare individual who could follow all of the avenues available. However, a forceful staff could be expected, collectively, to take advantage of every means at their disposal. Therefore, some research, part-time engineering practice, and participation in the activities of the professional societies should be going on. To carry on these phases of professional development, the opportunity as well as the time must be provided.

Research for student and faculty participation should not only be encouraged, but financially supported by the institution. A large appropriation is not always necessary for fundamental research and the rewards in the way of vitalizing teaching more than repay any expenditure made. It must be stressed that research should not be regarded as a faculty hobby, but as an essential third dimension to teaching and learning. A successful program of fundamental research will create opportunities for sponsored research.

Consulting Work

Part-time engineering practice gives perspective to engineering teaching besides assisting the faculty members financially. This is highly desirable when few members of the staff have had responsible experience in industry prior to entering teaching. Obviously, such part-time engineering practice should not be permitted to encroach on academic duties, but a reasonable amount is highly beneficial to the staff. Where opportunities for engineering practice are limited, much improvement can be realized if the institution itself makes a concerted effort to attract such work for interested staff members.

Participation of staff members in the activities of the professional societies should be encouraged and financially supported by the institution. This is not to suggest that the dues of staff members be paid by the institution, but attendance at a national meeting of at least one professional society yearly and local meetings might be profitably underwritten. These meetings afford an excellent opportunity for teachers to exchange ideas with other people in engineering. This exchange brings fresh ideas and concepts to the campus. Many ideas for improving teaching techniques, broadening of outlook, improvement of course objectives and gaining of professional recognition are a direct reward for participation in professional society activities. It is clear that the institution itself also shares in these rewards.

The survey showed a need for active responsibility on the part of the engineering educator. It is a grave indictment of the teaching profession that these former educators, in their experiences, were not permitted to assume serious responsibilities. Certainly professional responsibility is a distinguishing attribute one expects to find in any true profession.

Furthermore, in the denial of professional responsibility lies the cause of which the other dissatisfactions enumerated are merely the effects. Given responsibility, a faculty is in a much better position to work out its own salvation, so to speak.

One might well ask then what specific responsibilities should be given to the faculty. Space does not permit a detailed discussion of the collective and individual responsibilities which should be given faculty members. Generally speaking, the faculty should be given full responsibility in those areas in which it is collectively most competent to exercise responsibility and in those other areas essential to maintaining complete freedom of expression and action. Full faculty responsibility is needed in determining the objectives of the various disciplines of study, the curricula for attaining these objectives, and the development and efficient use of faculty talents in supporting the curricula. In order to maintain complete freedom, the faculty must be responsible for determining its own membership, emoluments, promotions and the apportionment of available academic funds.

Conclusion

Engineering teaching offers a clear challenge when it is recognized that the engineering educator is both engineer and teacher. When the engineering educator cannot grow as an engineer, it is inevitable that he will fail as a teacher. The challenge becomes increasingly more clear in the mission of engineering education to develop in students intellectual curiosity and engineering skill, a desire to accept broad responsibilities, the ability to think analytically and critically, inventiveness, a true sense of values and human understanding. To recognize this challenge, the engineering educator must experience it in his own life and to meet the challenge he must continue to grow in professional stature all of his life. To stand still is to fail.

Acknowledgment

The writer wishes to express his indebtedness to the many colleagues and former colleagues in engineering education who have contributed to the preparation of this paper, and, in particular, to Dean Ashley S. Campbell for many valuable suggestions.

First Iowa Thermodynamics Symposium

Recent developments in thermodynamics will be considered at the First Iowa Thermodynamics Symposium to be held April 27 and 28, 1953 at the **State University of Iowa at Iowa City.** The symposium will deal in particular with processes involving heat and mass transfer. Applications of the topics to be discussed will be found in the fields of jet engines and many other phases of gas dynamics. The symposium is designed for persons in the academic field and in industrial research engaged in advanced thermodynamics.

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Subject Admission Requirements of Engineering Colleges*

By M. I. MANTELL

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The catalogs of 126 engineering colleges were used by the writer to tabulate the subject admission requirements during the years 1949–50 and 1950–51.

* Presented at the Annual Meeting, Southeastern Section, American Society for Engineering Education, April 11, 1952, Clemson College.

TABLE I

TOTAL PRESCRIBED ENTRANCE UNITS ENGINEERING COLLEGES, 1949–51
(126 Institutions)

Number of Institutions	Number of Units Prescribed
3	0.0
1	2.0
2	2.5
3	3.0
5	3.5
3	4.0
2	5.0
3	5.5
8	6.0
9	6.5
13	7.0
4	7.5
20	8.0
2	8.5
9	9.0
11	9.5
14	10.0
3	10.5
3	11.0
3	11.5
2	12.0
1	12.5
1	13.5
1	16.0
Total 126	Median 8.1

These data are summarized in Tables I and II. Required units which were specified to be from one or more of several broad fields of study of from a choice of more than two subjects were not listed. Institutions allowing a choice of two subjects were not included in the zero unit column of either subject.

The trend in entrance requirements from 1895 to date shows a considerable change in the number of different subjects being specified, the number decreasing from approximately fifty-three to thirteen. Of the more common entrance subjects, algebra has shown very little change in the percentage of institutions requiring it during the approximately fifty year period. The subjects of physics, drawing and social studies have shown a gradual decline, since 1895, in the percentage of institutions requiring them. The percentage of institutions requiring plane geometry, solid geometry, chemistry, English, and foreign languages was higher in 1924–25 than in 1895, but decreased again by 1949–51; the sharpest decrease being in foreign languages. Trigonometry was the only subject showing a gradual increase during the entire period.

In terms of Carnegie units, the median number of prescribed units has decreased from 9.1 in 1924–25 to 8.1 in 1949–51. One institution presently sees fit to prescribe the entire high school program, thereby increasing the range of number of units prescribed from a range of 5 to 13.5 in 1924–25 to a range of zero to 16 at present.

TABLE II

SUMMARY OF ENTRANCE REQUIREMENTS FOR ENGINEERING COLLEGES, 1949–51
(126 Institutions)

Subject	% of Institutions Requiring Indicated Units						
	0	½	1	1½	2	3	4
Plane Geometry	2	0	97	0	0	0	0
Pl. Geom. or Adv. Alg.	—	—	1	—	—	—	—
Algebra	2	0	6	65	27	0	0
Adv. Alg. or Sol. Geom.	—	3	—	—	—	—	—
Solid Geometry	38	53	0	0	0	0	0
Sol. Geom. or Trig.	—	6	—	—	—	—	—
Trigonometry	61	32	0	0	0	0	0
Trig. or Adv. Alg.	—	1	—	—	—	—	—
Physics	55	0	29	0	0	0	0
Physics or Chem.	—	—	16	—	—	—	—
Chemistry	70	0	14	0	0	0	0
Biological Science	99	0	1	0	0	0	0
General Science	99	0	1	0	0	0	0
Science*	33	—	24	—	2	—	—
Science or For. Lang.	—	—	—	—	1	—	—
Foreign Language	79	0	0	0	14	2	0
For. Lang. or Soc. St.	—	—	—	—	3	1	—
Social Studies	51	0	36	0	8	1	0
Drawing	98	0	2	0	0	0	0
English	14	0	0	0	2	65	19
Health-Phys. Educ.	99	0	1	0	0	0	0

* Required units in addition to other science, when others are specified. Thirty-three per cent of the institutions do not require any type of science.

Articulation of High School and College

A tabulation of subject admission requirements becomes far more meaningful if it is also possible to determine to what extent the admission requirements are articulated with the college work in each institution. The extent of this articulation may become more apparent if reference is made to certain college courses related to the high school courses required for admission. Table III shows a summary and comparison of the high school entrance and related college course requirements.

From this table it appears that trigonometry is the subject which the colleges believe can be most effectively taught at the high school level; that is, sixty-five per cent of the forty institutions requiring high school trigonometry show their satisfaction with the high school treatment of the subject by not requiring it at the college level.

High school algebra is accepted, without college algebra, by forty-one per cent of the thirty-four institutions requiring two units of algebra for admission. The other entrance subjects (except plane and solid geometry, which are not given for college credit) are required, by the great majority of the institutions to be taken at the college level regardless of whether or not they were taken in high school. In some few instances special sections, carrying a smaller number of college credits are indicated for students having the high school subject; a few institutions indicate that special examinations may be taken which, if passed, may substitute for the college course.

The institutions which are willing to accept high school courses in algebra and trigonometry without their college equivalent tend to be those institutions which can be highly selective in admissions. However, none of these institutions will accept high school chemistry or physics in lieu of their college equivalents; nor do those institutions requiring high school physics and chemistry tend to require less semester hours in college, as may be noted from the range of credits shown in Table III.

Evaluation Of Admission Requirements

The records of 190 engineering students at the University of Miami were used in attempting to evaluate the subject admission requirements which would be most likely to affect success in the engineering school. Comparison of the college grades of matched pairs of students, one who had not and one who had taken the particular high school subject, were used as the measure of relative contribution of each entrance subject towards success in the engineering school. The pairs of students were matched initially by using equivalent percentile scores made on the American Council on Education Psychological Examination for College Freshmen. Grade point numbers of five for A, four for B, three for C, and two for D and one for F were used.

These data are shown in Table IV. The highest critical ratio of 2.67 was in the instance of chemistry—indicating a superiority (significant at the one per cent level) of those students entering with high school chemistry. Students entering with high school advanced algebra showed a superiority (significant at the three per cent level) in college algebra. Similarly students entering with high school trigonometry, mechanical drawing and physics tended to make higher grades than those without the high school background for the equivalent

TABLE III

SUMMARY OF COLLEGE ENTRANCE AND RELATED COURSE REQUIREMENTS
(126 Institutions)

Subject (H. S. Units)	No. Instit. Require	Instit. Req. in Coll.		Range of Coll. Sem. Credits
		Number	Per cent	
Algebra (0)	3	3	100	3 to 3.3
Algebra (1)	7	6	86	0 to 5
Algebra (1½)	82	74	90	0 to 5.3
Algebra (2)	34	20	59	0 to 5
*Trigonometry (0)	86	86	100	1.8 to 3.3
Trigonometry (½)	40	14	35	0 to 3
*Physics (0)	89	89	100	6 to 15.3
Physics (1)	37	37	100	6 to 16
*Chemistry (0)	108	108	100	4 to 12
Chemistry (1)	18	18	100	6 to 10
Drawing (0)	124	123	99	0 to 7.3
Drawing (1)	2	2	100	2 to 3.7
English (0)	18	18	100	6 to 12
English (2)	2	2	100	6 to 9
English (3)	82	81	99	0 to 16
English (4)	24	24	100	2 to 18
*For. Language (0)	106	1	1	0 to 12
For. Language (2)	17	0	0	— to —
For. Language (3)	3	1	33	0 to 4

* Includes institutions allowing a choice of subjects.

TABLE IV

SUBJECT COMPARISON OF COLLEGE GRADES
(Matched by A.C.E. Scores)

H. S. Course	College Course	No. Cases	Grade Pt. Mean With H. S. Course	Grade Pt. Mean Without H. S. Course	Critical Ratio
Adv. Alg.	Algebra	106	3.72	3.32	2.19
Adv. Alg.	An. Geom.	96	3.21	3.02	0.98
Adv. Alg.	Calculus	90	3.31	3.36	−0.23
Pl. Geom.	Trig.	50	3.52	3.16	1.16
Pl. Geom.	An. Geom.	48	3.21	2.96	1.00
Pl. Geom.	Des. Geom.	50	3.56	3.56	0.00
Pl. Geom.	Calculus	44	3.00	3.50	−1.73
Trig.	Trig.	146	3.82	3.55	1.50
Trig.	An. Geom.	120	3.23	3.07	0.90
Trig.	Calculus	120	3.28	3.43	−0.75
Sol. Geom.	An. Geom.	132	3.32	3.18	0.78
Sol. Geom.	Des. Geom.	152	3.74	3.43	2.07
Sol. Geom.	Calculus	130	3.44	3.38	0.33
Drawing	Eng. Draw.	150	3.95	3.84	1.05
Drawing	Des. Geom.	150	3.53	3.47	0.38
Physics	Physics	104	3.34	3.30	0.27
Physics	D.C. Mach.	62	3.19	3.23	−0.16
Physics	A.C. Mach.	42	3.38	2.86	1.79
Physics	Mechanics	58	3.38	3.19	0.83
Physics	Thermo.	44	3.23	3.50	−0.90
Physics	Stren. Mat.	44	2.77	3.05	−0.88
Chem.	Chemistry	148	3.39	3.07	2.67

basic college course—although the differences were not very significant.

However it is interesting to note that in most instances as the matched pairs moved into more advanced college work, the superiority of those with the high school background course decreased and even changed into the negative. Although the differences are not very significant, the data show such tendencies as students performing better in calculus for not having had high school trigonometry and worse in thermodynamics for having had high school physics.

A biserial correlation between entrance subjects and all 2086 college courses evaluated resulted in a biserial r of 0.07; the biserial r for 986 courses above the freshman level was 0.01—which indicated practically zero correlation between entrance and college subjects.

Such results seem inconsistent with what one would logically expect; however, subjective discussions with many of the students and faculty involved revealed a possible explanation. The students with previous high school instruction, when finding themselves in the same college class as those without previous instruction in the subject, tend to become overconfident and rely too much on previous knowledge. There is a tendency to slight the work as much as possible; repetition of much of the subject matter results in the course becoming tiresome, distasteful, and destructive of interest—fostering careless

habits of work. The students without previous high school instruction usually found it necessary to take their work more seriously, found it of greater interest and developed good work habits—which might account for a superiority in the advanced work.

Summary and Conclusions

Historically, subject admission requirements seem to have been those subjects which the colleges considered a necessary part of education, yet which could be handled adequately by the preparatory schools. Differences of opinion as to which subjects are a necessary part of education, differences as to which subjects can be done adequately by the preparatory schools, and the spontaneity of the development of American education, have resulted in the wide variation to be found in present subject admission requirements.

The 126 engineering colleges studied are apparently in complete agreement about five of the usual subject admission requirements being a necessary part of education; algebra, trigonometry, physics, chemistry, and English are required by every one of the colleges. They are, however, in considerable disagreement as to whether these same subjects should be taken in the high school only, college only, or in both high school and college. In all other listed entrance subjects there are disagreements as to whether or not they should be required at all, and if required, the location of training varies. Trigonometry and algebra are the only high school courses frequently accepted in lieu of the college equivalent; and these are accepted by only twenty per cent, or less, of the institutions whose catalogs were studied.

The engineering colleges, having specified admission requirements, do not seem to maintain a consistent policy in regard to the synthesis of the required high school courses with the college program. Certain engineering schools will require high school courses in some subjects and not require courses in these subjects at the college level. The same school will require other courses in both high school and college; and require still other courses at the college level only, regardless of whether or not the subject was taken in high school. The engineering schools which have no specific admission requirements are consistent; but consistency which apparently ignores or places little value on previous training is hardly sufficient.

The engineering colleges, in all probability, have found it difficult to be consistent or liberal in their acceptance of preparatory training because of the wide variations in the preparatory training and the usual emphasis in the preparatory schools on consumer instead of professional use of mathematics and science.

There seems to be no objective evidence validating the subject admission requirements which have been established for the various engineering colleges. The evaluative data presented in this study represents the results as found in a single institution; however, lacking contrary evidence, this data seems to allow the inference that (as similarly has been shown by many studies of liberal arts college admission requirements) there are no particular high school courses which lead towards success in the engineering school.

Engineering is based upon mathematics and the physical sciences, and an interest in and aptitude for these fields is important if an individual is to be a success in the profession. However, there is little point in the individuals' taking a full scientific program in high school to the neglect of other courses at least equally important. It would seem desirable for the engineering schools to advise entrance preparation with goals of: the building of a balanced background of general knowledge, discovery of the fields in which the individuals' interests and aptitudes lie, and a flexibility of program to allow the longest possible delay in making the final choice of, educational and vocational goal.

There seems to be evidence indicating that it might be preferable to require the

secondary training to be primarily in cultural or general education, instead of the traditional entrance requirements emphasizing mathematics and science. This would allow a depression of much of the non-technical portion of the engineering curriculum down into the high school, relieving the essentially crowded college program.

While the nation faces such a serious shortage of students entering the engineering colleges it might be well to consider interest and aptitude, above high school background, in selecting the students for admission. It would be difficult to estimate the number of potentially excellent students who have been denied admittance to engineering colleges because their interest in engineering developed too late for them to acquire the specified subject admission requirements, requirements based upon theories which apparently do not conform to fact.

Further Studies Needed

A study to determine the number and type of high school courses which would most efficiently indicate interest in and aptitude for engineering.

Additional experimentation on the feasibility of accepting high school courses in algebra, trigonometry, physics, chemistry and drawing in lieu of their college equivalents; or of giving college level courses in these subjects in the high school (the original intention of admission requirements).

A study of repetition of subject matter at the college level. This might be done by noting the effect of experimental groups taking upper level courses without the usual prerequisite of the basic course.

A study to determine whether or not adequate general education could be attained by greater emphasis on general education in engineering college admission practices, and by a more broadly integrated technical curriculum.

Additional evaluative data of current admission practices at other institutions, similar to that shown in Table IV, to supplement the data presented herewith.

Reserve this date . . . .

June 22-26, 1953

ANNUAL MEETING

UNIVERSITY OF FLORIDA

GAINESVILLE, FLORIDA

An Outline of Certain Processes of Reasoning in Research

By HENRY JAMES MASSON

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The tremendous growth of research in the last thirty years has directed attention to its organization, management, and procedures. Because of the large sums of money, facilities, and personnel involved, and the desire to use these effectively and efficiently, examination and analysis of all procedures in use are constantly appropriate. Although a substantial literature is developing in the area of the management of research and development, the strictly technical literature of the various experimental sciences is almost barren of specific information concerning research procedures, except occasionally a vague reference to the scientific method without, however, amplification as to how it is used as part of the research process. However, in the field of philosophy and logic, there is available an extensive literature on the scientific method, but comparatively few students, planning a career in scientific research, elect courses in these fields as part of their formal training. When such courses are elected, there may develop a feeling of frustration or nonapplicability of subject matter, due to the abstractness of treatment. Many of the more philosophical writers on the subjects are not experimental scientists, and as a result, their language, illustrations, and approach may seem unfruitful to the eager young scientist interested in research.

Such frustration is neither necessary nor desirable. The modern concept of the scientific method, when properly considered, includes a multiplicity of sequences from an awareness of a problem to be solved to its successful conclusion and constitutes a disciplinary and directive philosophy of substantial value. We are concerned here, however, only with certain complex reasoning processes and their influence on the design of experiments and the selection of an experimental path leading to the solution of a problem.

Because of the appeal of research as a means of satisfying the curiosity of individuals and the desire to add to our knowledge of man and his environment, an increasing number of individuals are entering the field and are beginning to learn something of its philosophy and practices. This paper has been prepared in order to stimulate more extensive study by this young group of the literature related to the scientific method in general, and that of logic in particular, and at the same time, to present certain aspects of the methodology of research from a fresh viewpoint. Although these remarks are directed principally to this new group, the experienced investigator may find here and there a point of interest or basis for reflection. An effort has been made to winnow some fundamental principles from a vast amount of material and establish a framework for use in the design of experiments. It has been undertaken with apprehension, because of its departure from the standard presentation and the somewhat unrestrained interpretation and application of classical concepts. Certain ideas will be presented by means of arbitrary, diagrammatic representations, which have been introduced, because most researchers have high structural visualization, and, therefore, may give clarity to the subject.

Instances and Their Treatment

All fields of knowledge employ certain terms to described particular concepts. Various expressions from the field of logic will be used frequently and defined as they occur. One of these, of immediate interest, is the term "instances," which may be defined as any single fact pertaining to a thing, a physical or chemical property, an attribute, or event, which may be investigated scientifically and used to form an hypothesis or theory. A related number of instances may be grouped so as to form a phenomenon, or several groups combined to give the phenomena.

Through chance observation and as the result of designed experiments man has learned various facts. Over the course of time, these facts have been verified, experimentally or otherwise, and allowed to accumulate to form a reservoir or storehouse of knowledge. It is from this accumulation that man, by varying degrees of sagacity, has chosen those single instances, or combination thereof, which intuitively he suspects will lead to a solution of a problem.

Classification

Among the various traits which characterize investigators is the desire for classification—the ambition to bring order out of apparent confusion and establish a basis for convenient use and understanding of facts and their relationships. The desire for an orderly arrangement of facts—a form of "factual tidiness" is inherent in the make-up of the true scientist who wants to have his knowledge organized in a readily available and usable form. Neatness and apportionment are essential to the peace of mind of the scientist, so that his reasoning processes will be unencumbered by any disturbing disarray. Scientists are not content with facts when seen in isolation.

A mere collection or accumulation of instances—facts—does not constitute a science any more than a pile of bricks is a house or other useful structure. Since research is a form of human action which results usually in the discovery of new facts, a sound and fruitful method must be found to group, or bind, the facts together for useful purposes. The aptitudes of the investigator are concerned not only with discovering new and isolated facts, but should go beyond, and be so developed as to extend to the perception of wholes or patterns and consequences thereof.

As classification is an important element of reasoning in research, a few comments may be helpful to indicate its significance. Classification is a mental process carried out by an individual and consists of noticing or detecting certain similarities in attributes or qualities of things or phenomena considered in determining the classification. Or, classification may be described as the process of recognizing or identifying at least one trait or point of similarity shared in common by a number of instances or phenomena, and mentally associating these in a single group or class. The system of classification used may be based upon established or acceptable concepts or a working definition tentatively postulated for purposes of exploration. A classification may be depicted by a diagram, chart, figure, or in tabular form, as, for example, in the Periodic classification of the chemical elements.

In making the classification, an appraisal of value may be applied. It is rated of high value if there are many significant points of similarity and of low value if there are only a few similarities. The more points of similarity the more homogeneous and satisfactory will be the classification.

It is a matter of common knowledge that some individuals, on rare occasions, and more frequently in the case of experienced investigators, have the uncanny faculty to select, from a vast array of diversified instances, those having certain common similarities and bring them into a given classification. In some cases, based upon their selections and reflections, prediction may be made of what will probably be observed in a designed experiment or indication of the path to be followed toward the solution of a given problem. Apparently, detecting similar-

ities or likenesses is, in some aspects, more difficult than recognizing dissimilarities. In any case, the attempt to establish order among facts is a difficult task at which few succeed significantly. It cannot be reduced to a set of procedures which, when faithfully followed, will guarantee success. Classification will be considered later as part of the process of hypothesis formation.

Preliminaries to Experimental Research

A number of preliminary procedures are usually involved prior to the physical design of any experiments as, for example, the application of dimensional and statistical analysis. We are concerned at this point, however, only with certain procedures which usually come before the application of these important mathematical tools. One of the first steps in a research, in which the objective is clearly defined, is to determine which elements of the solution are available in the literature, but have not as yet been correlated or treated as part of the approach to the solution of the designated goal. The procedure to be immediately described applies particularly to the individual who is just about to begin his first research and who, although well grounded in the fundamentals of the broad field of the research, has not worked sufficiently long in the limited area of the research to have become familiar, as part of his working knowledge, with the particular instances that are involved.

It is well to realize that the purpose of carrying out an investigation is based upon the desire to add to knowledge, irrespective of whether or not the results are to be applied immediately or perhaps in the future. In any case, the researcher is operating at the frontiers of knowledge and hopes, through a successful solution, to expand a limited portion of these frontiers.

One of the initial steps undertaken by the researcher with a problem to investigate is that generally known as the "literature search," the mechanics of which may be represented graphically as follows—Fig. 1:

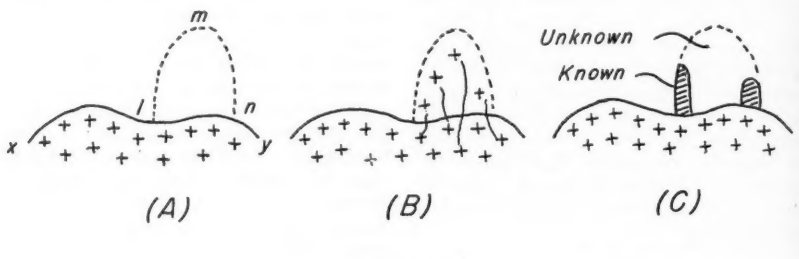

Fig. I

In Fig I–A, the solid line xy represents an arbitrary designation separating the area of knowledge, represented by crosses, from the unknown area. The dotted line lmn indicates a part of the unknown area circumscribed by the objective of the research. That is, if the investigation is successful, the new frontier of knowledge will be represented by a solid line xlmny. The boundary line xy is indefinite, located in a penumbra region and positioned by the skill (knowledge) and experience of the investigator. The line lmn is more so, the whole being a tentative arrangement for more solid construction. In Fig. 1–B, the instances from the known area, which the investigator suspects are part of the solution to the problem, have been transferred in a purposeful manner to the proposed area of investigation and thereby to begin the population of the region to

be added to knowledge. Fig. 1–C represents a segregation of related instances in the new area, thereby disclosing, both in magnitude and nature, known portions and unknown gaps to be filled. In other words, as a result of a careful study of the literature, it is disclosed that what was thought at first to be an area of which nothing definite was known now reduces to one of which certain portions are more clearly defined and other areas which must be investigated experimentally to develop the necessary information for completeness and inclusion within the new frontiers of knowledge.

Hypothesis Formation

This leads to a consideration of certain mental processes related to the design of an experiment and selection of experimental paths toward the solution of the problem. Whereas the various processes of classification operate on a certain intellectual plane, the intensive exercise of the same general analytical aptitudes can, in certain groups of individuals, give rise to syntheses and inferences of importance through the processes of reflective thinking and reasoning. In analyzing these processes, we may use a graphical approach, but with objectives and consequences of an heuristic nature.

It has been suggested that by means of classification a working basis may be established for extending the frontiers of knowledge. Occasionally, certain individuals, capable of varying degrees of significant thinking, and under free will, economic and other pressures, have gone an important step beyond classification and through uncanny insight, sometimes referred to as a flash of genius, discernedly take instances from this, that, or the other field, which, when fused together, result in a formulation which may be used as a basis for further exploration—the hypothesis.

Although the term hypothesis is frequently used in research parlance, it is desirable to review briefly its formulation, significance, and importance in the sequences of research procedures. An hypothesis is defined as a comprehensive but tentative interpretation of certain phenomena, to be considered as possibly true until there has been an opportunity, experimentally or otherwise, to bring all related instances into comparison. The initial hypothesis, pending verification, may be regarded as a "working" hypothesis, so that it may serve for immediate purposes of correlation and suggestive of a method of solution of a given problem. It is a tentative guess, or a scaffold, to aid in the construction of a more permanent structure.

A good hypothesis should: (1) bring together, in a simple manner, a given number of instances and interpret the connection between them; (2) be fruitful —fertile—that is, suggestive of significant deductions which are testable; (3) be comprehensible and not inconsistent.

In describing the creation and use of hypotheses, several terms are used. Two of these, induction and deduction, present difficulties in defining, because of the complexities involved and the evolution of interpretation which has taken place over the course of time by many minds. Both are concerned with thought processes. In its simplest form "induction" may be described as the process of reasoning whereby a selected group of instances are synthesized into a hypothesis and "deduction," the process whereby consequences are inferred from the hypothesis. On the basis of the foregoing, it has been advanced that induction is the reverse of deduction, but this is only true in the sense of convergence and divergence as illustrated by what follows. Many thought processes are both in fact inductive and deductive, depending upon the point of view during interpretation.

Classification has been treated as though it was an independent operation on the mind which stopped at mere classification. Actually, in many cases, while the process of classification is in process, the mind is not only seeing relations between instances, but also a possible interpretation of some phenomenon—that is, forming an hypothesis. The two opera-

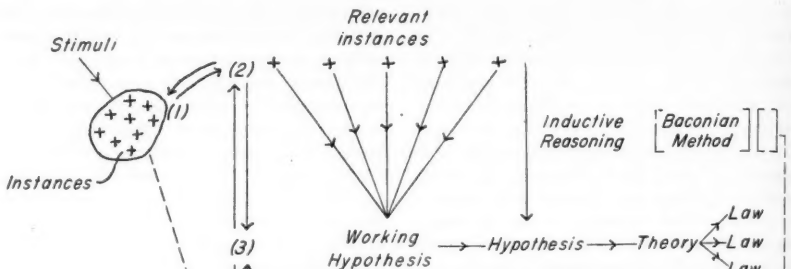

Fig II

tions may proceed simultaneously, so that in certain cases, particularly in new fields, the two processes are inseparable.

The relation between the processes of classification, inductive reasoning, hypothesis formation, deductive reasoning, and inferences is shown graphically in Fig. 2.

The above tends toward oversimplification. It is a condensation product which could readily be expanded to encyclopedic proportions. In the abridging process, certain concepts have been submerged and fine shades of meaning blended in the microdiagram.

In any case, it is not an expression of reasoning in the nature of a final product, but rather a mobile equilibrium product or condition in dynamic harmony with the state of knowledge at the time of formulation and the grasp of relations by the reasoner at the time of reflection. It consists of a multiplicity of reversible mental processes involving the sagacious selection and rejection of instances and consequences until a usable, consistent, fertile, and workable hypothesis is established which the mind (tentatively) feels is valid and which appears to give promise that it will be helpful in attaining the objective. However, the type of mind we are describing is probably never completely satisfied, but continues the process of selection, sorting and joining facts (jig-saw fashion) in an attempt to construct a composite picture in which all parts fit. One has no measure of the conscious or subconscious trials and errors which have taken place on a mental blackboard of some investigator until a flash thought—a mental leap (inductive)—points the way toward a simple formulation (hypothesis) in which all relevant instances are harmoniously absorbed or consolidated. It is a method of approximation. Hypotheses are tentative and cannot, in many cases, be exhaustively verified. Therefore, the frequent use of the word "probable" in connection with hypotheses.

Reasoning Process

In the beginning of the reasoning process, interchange of instances takes place between (1) and (2) (Fig. 2) until a combination or classification is attained

which is amenable to inductive reasoning. The next procedure, resulting in a hypothesis, is represented by the interaction between (2) and (3). These operations or thought processes may proceed instantly, or extend over varied and sometimes long periods, depending upon the complacency of the conceiver. However, such a mind, once started, and perhaps in a state of mental momentum is not contended to stop at (3). Whether, as indicated, through an idea momentum or vision, one may suspect consequences of the generalization or hypothesis. This leads to the process of deductive reasoning and the proliferation of consequences as represented by step (3) to (4). If, as the result of deductive reasoning, the consequences appear illogical, improbable, impossible, unreasonable, or contrary to experience and scientific law, the mind (the true scientific and unbiased) re-examines each deduction, reasons and modifies the hypothesis, until eventually complete harmony exists between (3) and (4). In this process, it may be necessary, and usually is, to examine all aspects. In other words, before the mind is satisfied, complete inferential agreement must exist between all phases and stable equilibrium prevails between stages (1), (2), (3), and (4).

Due to the limited comprehensiveness of the normal intellect, all consequences of an hypothesis are usually not deduced by a single mind and confirmed by recourse to memory. Additional significant deductions may be suggested by co-workers. All consequences are, therefore, listed and confirmation sought in the literature or experimentally. This brings us to an important observation. As the result of the foregoing treatment of instances, a new and unsuspected experiment to be tried may be indicated, or even a new field for research suggested. As indicated, a good hypothesis should not only weld together, in homogeneous agreement, a given number of instances, but should also suggest consequences of importance. Such consequences, when confirmed experimentally and their validity established, become instances to be added to the storehouse of knowledge and form the basis for a further expansion of the frontiers of knowledge.

The greater the number and impressiveness of instances included initially, the broader and more fundamental will be the resulting hypothesis. If based upon a sufficiently comprehensive number of instances and confirmed by an adequate number of experimentally proven consequences, the initial "working hypothesis" assumes the status of a valid hypothesis, and upon further confirmation, gives rise to various theories. If, over a long period of time and exposure to testing, no exceptions are found to a given relationship, a law of science may be formulated.

Laws of Nature and Science

A law of nature is an order or relationship detected in nature by some human observer based upon his investigations of an area of nature. It is a simple statement of facts, which may, in some cases, be expressed in mathematical form. The laws of science, in general, are not directly concerned with specific things, but rather with abstractions from them. For example, the law of gravitation is concerned with the forces acting between bodies, but there are numerous physical and chemical properties about which the law is silent, or uncommunicative. A law of nature is a summarization, or integration of a number of facts, the relationship or significance of which may be explained or clarified by a theory.

The nascent hypothesis and deductions therefrom are, up to this point, the product usually of one mind with its limitations, inadequacies, and importantly, prejudices. The originator, having exhausted all combinations and processes of reasoning and confident of his conclusions, and having faith in the integrity and sympathetic understanding of his fellow workers and the mutual desire for the advancement of knowledge, exposes and discloses the results of his reasoning processes by publication or otherwise.

Now the whole process begins anew. Compatible minds, interested and expertly familiar with the field of knowledge involved, dissect, analyze, reorient their views and allow an independent reasoning process free rein to evaluate the results of the creator of the new hypothesis. If we look upon the original hypothesis as representing equilibrium, we now find, unless all who study it agree with the premises and conclusions, that conditions (criticisms) will be advanced which have the effect of disturbing the equilibrium, which, in turn, will result in a shift to a new equilibrium (modified hypothesis). The extent of the resulting modification of the original hypothesis will depend upon the nature of each criticism and the number of confirming investigations involved. If, in time, general agreement of a modified hypothesis is reached, the resulting product will probably be superior.

Because of the interest developed, study of the hypothesis does not cease at this stage. Other minds, ordinarily not concerned with the field of research represented by the hypothesis, become interested and see applications in their particular field, and undertake investigations to determine its applicability. This transfer to another field may result in further modification. And so it will be seen that any hypothesis may undergo a sort of fission process.

At times, several rival hypotheses may be extant. Under these circumstances, a crucial experiment (experimentum crucis) is undertaken. It is a critically designed experiment to provide data with which one hypothesis is consistent and which is inconsistent with another.

A given number of instances may be selected to constitute a particular field of knowledge. The number of such instances may be large. One investigator may choose a certain group of instances and formulate an hypothesis while another investigator may choose another group from the same field and formulate what appears to be a different and unrelated hypothesis. But this is not necessarily so. All the instances involved in each case came from the same classification and from the nature of the classification process must have had some characteristics in common. This leads to the suspicion that both hypotheses are related and may be integrated into a single super-hypotheses. This development is illustrated by the contributions of Copernicus, Galilei, Newton, and Einstein.

There remains another situation which illustrates a still different mechanism of reasoning and which has been very fruitful as a means of formulating a working hypothesis to aid in the experimental design of some investigation or establish a basis of explanation for consequences not verifiable experimentally. In the cases studied thus far, the conscious mind is the one considered as functioning. We must give some consideration now to the role of the subconscious mind, although the distinction between the two is very indefinite. In this discussion, the subconscious mind is considered as exerting an effect when the body is completely dissociated from environmental factors disturbing to thinking and engaged in the automatic operations involved in the performance of familiar actions. While in such a state, and in search for a solution to a given problem, instances may be assumed which are not found in any literature or recalled from memory, and with intuitive faith in the reasonableness of the assumptions, the mind proceeds inductively to create an hypothesis and deduce consequences. The consequences may be constructive or fantastic. On the basis of such assumptions, substantial advances were made by earlier thinkers. This is illustrated by the kinetic molecular hypothesis.

The foregoing suggests another approach to hypothesis formation. This is the use of analogy. We may not observe a direct or structural relationship of instances to form an hypothesis, but there appears to be similarities from which others may be inferred. An analogy is a resemblance of relations which may be used for reasoning and from the likeness in certain respects we may infer that other and more important relations exist.

We refer to the flow of liquids as

analogous to the flow of electricity, the structure of the atom as analogous to the solar system and cybernetics reasons by analogy between the mechanisms of control and of communication in the animal and various mathematical machines Such analogical reasoning may be fruitful and help to visualize relationships, but there are dangers. We must, however, distinguish between circumstantial evidence and direct evidence which may lead to a false analogy. Analogy invades and influences our thinking and, although helpful in research, it should be used with caution and not allowed to lead to hasty generalization.

There is a last approach used occasionally and not always looked upon with favor, but, nevertheless, it may indirectly result in valuable contributions and may give some encouragement to the novice and act as an expedient to the experienced investigator. This is the "wild" experiment. The impression exists, and soundly, that the larger the accumulation of instances (knowledge) of the investigator, the greater the probability of his success in solving a given problem. But this is not necessarily so. Too much knowledge may lead to complacency and too much faith in the inviolability of generally accepted hypotheses, theories, or laws, and may result in the rejection of any suggested experiment which is an apparent conflict with them. Valuable discoveries were made by men who did not know they were violating some established theory. Such reckless suggestions leading to "wild" experiments have resulted in unusual discoveries. It is pleasant to have a deduction confirmed experimentally, but it is an experimental result which is at variance with theory, which may be productive of new knowledge and new fields to explore and which point to a path for the advancement of civilization.

Conclusion

In conclusion, it should be emphasized that hypotheses usually have a short life, theories come and go, but the facts with which they are concerned remain the same. The properties of benzene have not changed since it was first discovered, but the suggested arrangement of the atoms in the molecule, the interpretations of the formula and the various theories advanced to explain its action have changed—but again, not the properties.

Although an hypothesis may be rejected in due time, its formulation may not have been a complete waste of time and mental effort for experience and a study of discarded hypotheses have shown that when such hypotheses meet the usual specifications and are properly worked upon, they frequently produce more useful results than unguided observations. In fact, a constructive advancement has been made when new experimental evidence indicates the untenableness of a given hypothesis and it is replaced by one more in accordance with the newer evidence.

No scientific law or theory has ever given an explanation of why anything happens, that is, what makes it happen. They explain how things happen, but not why. Although much has been written on the theory of causation, it is sufficient to state, at least in this treatment, that the so-called cause is just a statement of the set of conditions which precedes or accompanies an effect.

Summary

Because of the limited scope of this paper, of necessity many details and issues have not been included. The principal concepts, conditions and procedures outlined for the idea formation phase of an investigation may be summarized as follows:

(1) An environment satisfactory for research—social, political, economic, and technological.

(2) An individual, or organization, interested and qualified for research and adequately sponsored.

(3) Sources of problems for research which act as "thought starters" and create an awareness of a subject to be investigated—an incitation.

(4) The selection and definition of a problem to be investigated.

(5) The concentration of the mental faculties of an investigator on the objective and scope of the problem until it is thoroughly understood and feasibility determined.

(6) The gathering of all information related to the problem by means of the literature and other surveys in anticipation of the disclosure of instances, hypotheses, theories, and methods which are suspected to be related to and suggest a solution of the problem. The information should be recorded on 3 × 5 cards and in a notebook.

(7) The sorting, rearranging and classification of the information as a basis for the determination of the known and unknown portions of the circumscribed area of the proposed research. See Fig. 1.

(8) In the case of the unknown areas and in tthe absence of any hypothesis, theory, or law suggestive of an experimental approach toward the objective, the synthesis of a "working hypothesis" the deductions from which may indicate an attractive path of high certainty toward a solution of the problem.

(9) The discriminate sorting and purposeful selection and classification of instances as a basis for reasoning. It will be helpful generally if these are arranged as in Fig. 2, thereby bringing more of the reasoner's faculties into action.

(10) The implanting of this conception —mental image, together with the objective sought, in the mind of the investigator for his reasoning powers to work upon. This is an "incubating" period.

(11) The elimination of all distractive influences or environmental factors, which, during reflective thinking, would prevent concentration on the purpose at hand.

(12) The period of "digestion" during which the conscious and subconscious mind is constantly and unrelentingly pressing for a simple formulation—hypothesis.

(13) Do not strain for a solution to the point of mental and physical exhaustion. When not making progress set the problem aside completely and allow the mind to wander and the investigator engage in a non-related, diverting, and pleasant activity stimulating to the imagination and emotions.

(14) After a period of rest and relaxation, the gradual emergence of an idea for a semitangible synthesis—to be written down—as an initial working hypothesis. Such ideas may emerge unexpectedly at any time, place, or under normal or unusual circumstances.

(15) Making deductions—written down —as in Fig. 2, and then an interplay between (1), (2), (3), and (4), but without losing sight of the purpose of the investigation. One of the inferences should indicate a solution to the problem. At times, the mind may by-pass this step and go directly to the solution of the problem.

(16) The design of experimental equipment and procedures to confirm inferences which indicate a solution of the problem or confirm the solution suggested in 15.

There can never be any guarantee that the faithful application of the foregoing procedures will lead to a successful solution of a problem. However, when through constant application, they become an integral part of the investigator's "working tools," they eliminate careless thinking and help to establish a basis for a possible solution. That is, the mind follows an operative technique which can be learned, applied, but always under control. We may learn the fundamentals of an art or procedure under competent guidance, but it is only through constant practice or application that a high degree of skill is attained. Therefore, the only path to success in research is the constant practice of research.

In a subsequent paper, a "flow-diagram" will be offered which will outline the various sequential steps usually followed from the conception of a problem to be investigated to its solution.

Suggested Collateral Reading

(1) "How we think." John Dewey. D. C. Heath & Company, N. Y., 1933.
(2) "Scientific Method." F. W. Westaway. Blackie & Son, London, 1924.

(3) "A Philosophy of Science." W. K. Werkmeister. Harper & Bros., N. Y., 1940.
(4) "The Basis and Structure of Knowledge." W. K. Werkmeister. Harper & Bros., N. Y., 1948.
(5) "An Introduction to Logic and Scientific Method." M. R. Cohen and E. Nagel. Harcourt, Brace & Co., 1936.
(6) "The Principles of Reasoning." D. S. Robinson. Appleton-Century-Crofts, 3rd Ed., N. Y., 1936.
(7) "Introduction to Reflective Thinking." By Columbia Associates in Philosophy. Houghton-Mifflin Co., 1923.
(8) "Philosophy, an Introduction." J. H. Randall and J. Buchler. Barnes & Noble, N. Y., 1942.
(9) "The Genius of Industrial Research." D. Killeffer. Reinhold Pub. Co., 1948.
(10) "The Path of Science." K. Mees. John Wiley & Sons, 1946.
(11) "The Art of Scientific Investigation." W. I. B. Beveridge. W. W. Norton & Co., N. Y.
(12) "The Way of an Investigator." W. B. Cannon. W. W. Norton & Co., N. Y., 1945.
(13) "The Scientist in Action." W. B. George. Emerson Books, Inc., N. Y., 1938.
(14) "How to Solve It." G. Polya. Princeton University Press, Princeton, N. J., 1948.

Industrial Engineering Summer School

A three day summer school sponsored by the Industrial Engineering Division of A.S.E.E. will be held at the University of Florida starting on Saturday, June 20. The theme for the conference will be "Quantitative Measures in Industrial Engineering Courses." The program is designed to acquaint the teachers with the recent developments in applying mathematical measures to all phases of the profession. Substantial progress has been made in the last two years, through the use of statistical mathematics, probability theory, linear programming, and similar techniques, which opens many new opportunities for research and development in motion and time study, production control, plant layout, cost control, process planning, etc. Instructors, who have been instrumental in this development work, will teach the several sessions. The program of the conference is as follows:

Saturday, June 20	1:30	Objective of the Program
	2:00	Motion Study
	3:30	Time Study
	7:30	Industrial Organization
Sunday, June 21	1:30	Plant Layout
	2:30	Materials Handling
	3:30	Manufacturing Costs
	7:30	Process Planning & Tool Design
Monday, June 22	8:30	Examination Fundamentals
	10:30	Project Method of Instruction
	1:30	Operations Research Approach
	4:00	Roundtable Discussion and Summary

The Summer School Committee consists of:

Howard P. Emerson
Grant Ireson
Robert H. Lehrer
Earl Martinson
Joseph Moder
Everett Laitala, *Chairman*

For further details address Professor Everett Laitala, Mechanical Engineering Department, Case Institute of Technology, Cleveland 6, Ohio.

The Electrical Engineering Curriculum—Present-Day Problems and Time Limitations

The following are condensations of papers presented at the first conference on Electrical Engineering held at the Annual Meeting at Michigan State College, June 25–29, 1951.

Mid-Century Trends in Electrical Engineering Curriculums

By R. G. KLOEFFLER

Head of Department of Electrical Engineering, Kansas State College

The analysis which is to follow covers the curriculums of 79 accredited colleges in electrical engineering. Seventy-four of these colleges offer a 4-year curriculum and the other five have adopted a 5-year period. The locations of the colleges range from Maine to California and from Minnesota to Texas, with stops at most of the points between. The schools included vary in size from the largest universities to some of the smaller state colleges. The analysis was based on the latest catalogues available and, except for a few cases, covered the 1950–51 curriculums. The aim in this analysis has been to get a cross-sectional picture of American college curriculums in electrical engineering at the mid-century.

The classification of subjects which is to be used in the data which follow will not meet the entire approval of any E.E. teacher. However, it may serve as a basis for comparison. In the preparation of this analysis, the author makes no claim for infallibility in the interpretation of subject matter covered by the description of courses given in college catalogues. All figures covering credit have been reduced to the semester-hour basis.

The analysis shown in the following table is largely self-explanatory. The reader should note that the figures shown in parenthesis are averages for the schools having a 5-year curriculum.

Reference to the totals given in the analysis under general education shows that at the mid-century the 4-year E.E. curriculums contain an average of 7 credit-hours in social science and 7.6 in the cultural sub-group. The average of the combined social and cultural sub-groups (general education) is 11.6 credit-hours. (The average of the combined sub-groups is not equal to the sum of the other averages since some schools may offer only social or only cultural subjects.) The combined average of 11.6 for the 91 per cent of all colleges which require subjects in general education indicates that we are requiring approimately one-half of the 24 credit-hours recommended by one of the committees of our Society. If we add the average number of credit-hours required in English language, 8.2, to the total for general education, we arrive at an average of approximately 20 credit-hours of work which is nontechnical in nature.

Conclusion

In conclusion, two trends have been shown by the foregoing analysis.

1. The introduction of options in the senior year of 4-year curriculums. For

the colleges covered by this analysis, 62 per cent still retain a single general curriculum. However, in at least 10 of these institutions, some specialization is available through the selection of electives by the student. In the 38 per cent of schools offering options, all offer an option in electric power and in communication and electronics. In addition to these options, there are a few scattered examples of op-

ANALYSIS OF 79 ELECTRICAL ENGINEERING CURRICULUMS
(74 4-year and 5 5-year)

	Credit range (1)	Average credit (2)	Number colleges offering (3)	Per cent (4)
I Mathematics				
(a) College algebra	2–5	3.2	43	58
(b) Trigonometry	1⅓–5	2.8	42	57
(c) Anal. geometry	2–6	3.8	66	90
(d) Calculus	4–20	8.3	71	96
(e) Diff. equations	2–6	3.0+	51	69
(f) Integrated math.	4–10	—	20	27
Total Mathematics	9–28	20.0(23.6)*	74	100
II Physical Science				
(a) Chemistry	4–12	8.0(9.8)*	74	100
(b) College physics	5⅔–20	11.0(13)*	74	100
III English Language				
(a) Composition	2–12	6.0(6.8)*	73	99
(b) Speech	1–4	2.2(3.4)*	43	58
(c) Tech. reports	1–6	2.3(3.3)*	28	38
Total English	0–14	8.2(13.5)*	74	—
IV Engg. Craftsmanship				
(a) Drawing & desc. geom.	2–10	5.5(6.8)*	74	100
(b) Shop	⅔–6	2.5(3.0)*	42	57
V Engg. Fundamentals				
(a) Applied mechanics	2⅔–7	5.1+(6.6)*	74	100
(b) Fluid mechanics (or Hydraulics)	2–5	3.0	45	61
(c) Thermodynamics	2–7	3.7	59	80
VI Technical Subjects				
(A) Electrical				
(1) Common subjects				
(a) Basic E.E. (electric circuits & magnetism)	2–10	4.9(5.5)*	72	97
(b) A-c circuit theory	2⅔–10⅔	5.8(9.5)*	73	99
(c) Elec. measurements	1⅓–6	2.8	43	58
(d) Basic electronics	2⅔–9	4.4(5.4)*	68	92
(e) D-c machinery	2–7	4.2(4.6)*	67	91
(2) Electric power group				
(a) A-c machinery	4–18	8.3(11)*	74	100
(b) Electronics (industrial, etc.)	2⅔–8	4.5(8.0)*	41	
(c) Transmission & distribution	2⅔–9⅓	4.0(5.0)*	38	
(d) Illumination	2–4	2.3(4.0)*	11	
(e) Transients	2–4	2.6	16	
(f) Design	⅔–8	3.3	22	
(g) Electives	2–13	7.4(6.0)*	22	
(h) Option	⅔–27	5.5(7.6)*	34	

* Five-year curriculums shown in parenthesis.

ANALYSIS OF 79 ELECTRICAL ENGINEERING CURRICULUMS—*Continued*

	Credit range (1)	Average credit (2)	Number colleges offering (3)	Per cent (4)
(3) Electronics & communication option				
(a) A-c machinery	4–16	6.9(7.3)*	42	
(b) Electronic circuits, etc.		4.5(9.1)*	21	
(c) Network theory	2–5	3.5(4.5)*	18	
(d) Communication (radio telephone, television)	4–15	8.8(9.1)*	39	
(e) Electromag. waves (UHF)	2–5	3.4	21	
(f) Option	2–27	5.0(10.4)*	28	
Total electronic & communication		23.4	35	
(B) Nonelectrical				
(a) Heat power engineering	1–8	3.7(5.2)*	57	77
(b) Mechanics of materials (Strength of materials)	2–8	4.4(5.9)*	73	99
(c) Metallurgy	2–3	2.4	6	8
(d) Surveying	1–5	2.5	40	54
(e) Engineering economics	2–9⅓	3.7+(7.4)*	27	37
VII Electives				
(a) General (free)	3–18	7.4	33	45
(b) Technical	3–16	7.5	34	46
(c) Nontechnical	3–15	6.5	24	33
VIII General Education				
(A) Social Science Group				
(a) Economics (general)	2–8	4.0(4.5)*	47	64
(b) Sociology	2–9	4.0	10	13
(c) History (industrial)		4.3	7	10
(d) Government	2–8	3.4	20	27
(e) Psychology	2–6	4.0	5	7
(f) Comprehensive	1–9	5.6	15	20
Total Social Science	2–21	7.0(12)*	64	87
(B) Cultural Group				
(a) Literature	1–6	4.2	17	23
(b) History	2–10	5.0	19	26
(c) Philosophy	⅔–6	4.0	3	4
(d) Civilization	1–16	7.2	12	16
(e) Comprehensive	3–12	6.1	10	13
(C) Electives		(9.0)*		
Total Cultural Group	1–22	7.6(17)*	41	55
Total Social Science & Cultural (Humanistics)	3–28	11.6(29)*	67	91
Total credit-hours	126–160	144(174)*	73	

* Five-year curriculums shown in parenthesis.

tions in business administration, illumination, industrial, and physics. One school lists a total of four options.

2. A secondary trend has been an increase in the humanistic-social content of the curriculum. This trend carries only half way to the goal set by our Committee on Engineering Education After the War.

Professional Education in Four Years

By EDWARD R. SCHATZ

Assistant Professor of Electrical Engineering and Industrial Administration, Carnegie Institute of Technology

Professional education in the broadest sense of the term is not a four-year matter. It is education that starts during the years of college (perhaps even before) and must continue for many years after graduation. It is education that must include a program of college training and an internship or apprenticeship in the years immediately following college where very often teacher and student are the same person. It is education that must continue throughout a career if that career is to be truly successful.

It certainly goes without saying that during the years of formal schooling, the college or university is directly in charge of guiding these educational activities, although it is equally clear that the responsibility for doing the learning is directly that of the student.

After college the direct responsibilities of continued professional education fall to the graduate and the industry that employs him. This placing of direct responsibility for continued learning after college is not meant in any way to absolve educational institutions of their responsibilities in the post-school period. In every activity of the young graduate, his college is vitally, if only indirectly, concerned. One of the responsibilities of an educational institution is to provide instruction and training during the formal schooling that will equip the student to make future learning effective no matter in what situation that learning may occur, be it learning from text book and professional magazines, or learning in the postgraduate course offered by his company, or, the most difficult to do well, learning through experience gained in dealing with others.

What can a college do during its very important but brief period of education to train a man to full professional competence? What can a college do to carry out its own responsibilities and to make the student realize and carry out his both during and after the college years? How long should the formal schooling process go on?

Instruction Aims

At Carnegie Tech we believe these questions are answered by a four-year plan of instruction with the following aims:

(1) A thorough understanding by each student of the nature and use of the fundamental knowledge in the fields covered by the student's profession, and the attainment by the student through his own efforts while in college of a set of values which may be used as a guide for thinking and action.

(2) A philosophical outlook and breadth of knowledge which will enable him to deal effectively with the social, economic and political problems of his professional life and his life as a citizen.

(3) The development of an orderly way of analytical thinking in the use of the fundamentals of all fields.

(4) The ability to learn for himself through experience and to make effective use of this learning in advancing his professional career.

A curriculum to carry out these aims can be divided into two classifications—the basic courses in both the physical and social sciences, and the technological courses.

In point of time at my school, the basic courses in the physical sciences occupy about one and one-half years of the four-year program; the technological courses—about one and one-half years; and the basic courses in the social sciences and the other courses in this area—about one year.

I feel sure this division of the time, the names of the courses and much of the subject matter covered are essentially the same as in many other technical schools, but success in the achievement of the main aims is found much more in how these courses are taught than in the particular curricular areas that have been covered. Each of these stems—the basic science and the technological—has as its reason for existence the carrying out of the four main objectives and herein lies the unity which I believe significantly characterizes professional education during the college years. The forces of education are not divided. Each curricular area is designed for training in fundamentals, for establishment and use of clear methods of analysis, for extension of knowledge and skills to other fields and for learning from experience.

Moreover, the functions of the various curricular areas can be made complementary. For instance, a particular class discussion in history concerning methods of historical analysis can help establish good analytical methods for a concurrent physics or mechanics course. A more complete description of such possibilities may be found in reference one (1).

One Direction Program

In this singleness of purpose, this unity, there is teaching strength. There is, in addition, another outcome of this teaching method. It is the economy of a program that is all pointed in one direction. There is no one in the wagon dragging his feet —no one teacher wasting the time of another. For example, there is no physics instructor tolerating poorly written work, thereby effectively teaching poor English and thus tearing down the efforts of the English Department. The result of this is an economy of time spent in reaching the stated objectives. The fact that great saving of time can be made in this way is one of the reasons why I believe adequate undergraduate education can be completed in four years.

How does one decide on what courses to put into a curriculum to carry out the above objectives, and what to put into the courses? It is not an easy matter to build such a curriculum by putting together various blocks of subject matter and then teaching that material by the methods described. There is a constant struggle between covering ground and using a minimum amount of subject material to amplify one of the objectives. There is, of necessity, a minimum content for each course, but this content should come as a result of planning and should not anticipate it. To design the curriculum and the courses in it, one should act as a teacher, not a subject-matter specialist. For example, the humanistic-social program at Carnegie occupies about one year of the four-year program and, as such, curriculum planning becomes a hopeless task if done from the point of view of total subject matter a student must master. The planning can only be undertaken without complete frustration if the planner remembers that the student has not one year to learn but a lifetime if he is trained properly. An example of course planning for freshman history may be found in the second reference (2).

Summary

Let me summarize the reasons I believe that this formal part of education should and can be a four-year program. In that time, the fundamental principles and knowledge necessary for continued learning in fields of interest to the engineer can be established and used professionally in many examples. The method of teaching described makes this possible in the four-year period. Secondly, there are sound reasons for getting a man into the post-school education period as soon as possible where he must accept sole responsibility for his learning, must make his start on a professional career, must apply in a real situation—and not a schoolroom experience—his knowledge and method of attack and, therefore, where he begins the most difficult task of learning of all—learning from experience. For the

average student I do not believe that this introduction to such learning should be unnecessarily postponed.

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Curriculum Size 5

[A somewhat condensed first portion of paper]

By E. E. DREESE

Chairman of Department of Electrical Engineering, The Ohio State University

I. *Introduction*

The hope for engineering education is that the educators are perennially dissatisfied. The curriculum is a hair shirt fashioned and refashioned, patched and repatched to fit a boy who has become a man.

II. *A Brief History*

Engineering curricula in this country had their origin in the general colleges in the middle of the 19th century—100 years ago. The philosophy of the arts college was early impressed upon the engineering teachers. At that time engineering education could be covered in one year.

Early in the 20th century the engineer became aware of his importance to our civilization and had a growing and embarrassing realization that he had little understanding, or interest even, in that civilization and its emerging social and human problems. The engineering journals of the times are replete with surveys, discussion, and reports on "culture" as it was called.

Between the world wars some of this "cultural" content came grudgingly back under the new name of "social-humanistic" studies but it was not until the 2nd world war that a committee of this society recommended that 20% of the student's educational time be devoted to these subjects.

In addition, the two world wars dramatized for the public and engineers alike that engineering science was growing exponentially—at the scientific roots—as distinguished from the foliage of mere gadgetry. This is probably no better illustrated than in electrical engineering itself. Prior to World War I there was only one fundamental within electrical engineering —circuits. After that war electronics became a basic electrical fundamental. Now after World War II a new fundamental has come into electrical engineering itself —field theory. Wave guides, resonators, radars, and antennas require this new fundamental. The rise of the various types of computers and servomechanism are increasing curricular pressures for extensions of the fundamentals in mathematics and circuitry.

Historically, too, there is the emerging sense of professionalism in engineering which envisions that the engineer be educationally equipped both in general and special education at a level compatible with professional status. Where should engineering fit in the scheme of professional education? It now requires 7 years for a first degree in medicine; 6 years for law; 6 years for veterinary medicine; pharmacy and optometry require 5 years. Four years are required for nurses and dental hygienists.

III. *The Post-war Dilemma*

In 1944 there were searching introspections by every institution of learning with committees working on curricula for a

changed post-war world. Engineering curricula were in particular trouble. There was compelling pressure to increase each of the three major portions of program—the social content, the fundamental content and the professional content. The descriptive courses of yesteryear were already gone. Improvisations and make-do shifts became the vogue. Mathematics was cut here—final examinations were dropped there. Paul was robbed to pay Peter. In general both fundamental and technical professional content were invaded in an attempt to reach the magic 20% for social content. Most have despaired while still short of that goal. The growing question still lingered—could the engineering schools keep faith with professional standards by turning out a product with even less professional engineering competence than they had hitherto? Was engineering to be some sort of low level profession?

IV. *The 5-year Solution*

After wrestling with these problems for months on end certain schools decided that the size 4 shirt was just too small for maturing engineering. It was realized that the 4-year concept was simply a tight fitting hand-me-down from our liberal arts forebears. Tradition, blindly accepted, becomes simply habit. Such thinking is necessary to gain freedom of mind.

As of today there are at least four schools with 5-year curricula for a bache-

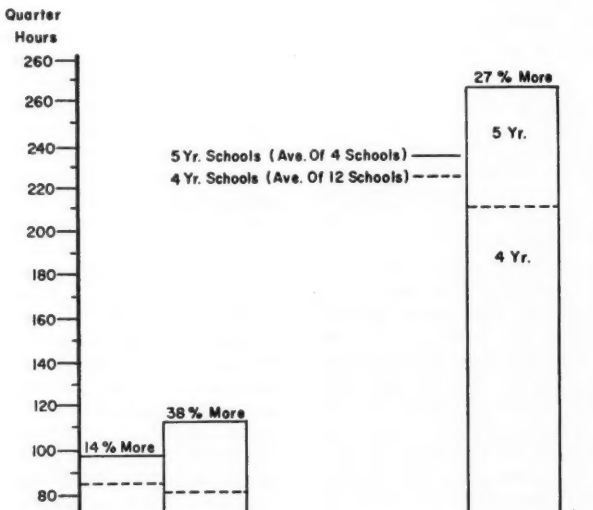

FIG. 1. Comparison of composite C.E., Ch.E., E.E., and M.E. curricula.

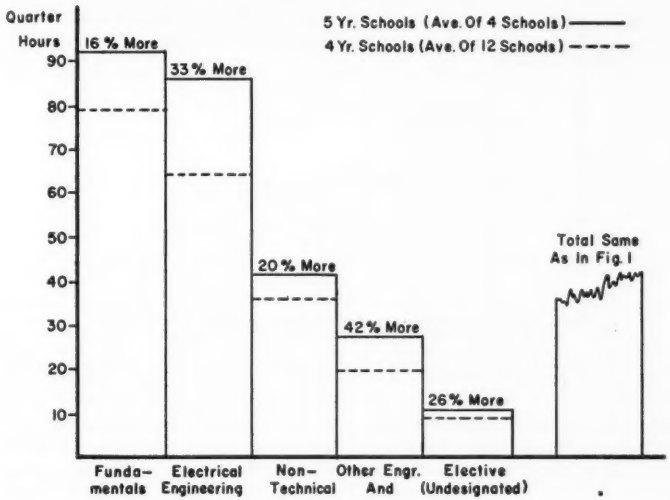

FIG. 2. Comparison of average electrical engineering curricula.

lor's degree in engineering. There are others with optional or variant programs.

V. *Curriculum Comparisons*

Before going into comparisons of existing 5-year and 4-year curricula we should be reminded that 5-year curricula have their individual differences just as do the 4-year curricula. Educational experimentation still goes on but those wearing the size 5 garment are not suffering the shortness of breath of those wearing size 4. No 5-year school claims its curriculum is perfect—it simply claims it is better, and timely.

In the following comparison charts an attempt is made first to eliminate individual differences in 5-year and also in 4-year curricula by comparing composite curricula of the two types. This is done for a group of curricula in Fig. 1 and for electrical curricula in Figs. 2 and 3.

A caution is necessary in interpreting this figure as well as the succeding ones. The figures represent the comparison of present 5-year curricula and *present* 4-year curricula as revealed by latest available bulletins. The caution mentioned is against interpreting the 4-year values as though they were the *old* 4-year values of the present 5-year schools.

The term "fundamentals" here includes mathematics, physics, mechanics, chemistry and drawing.

The most significant difference is shown in technical content. This 38% difference is due only partly to the fact that 5-year schools increased technical content over their previous 4-year content. Probably the largest portion of this 38% is due to the diminution of technical content of 4-year schools to make room for increasing non-technical content.

The non-technical content of the 5-year curricula is 20+% of the total content of the average of the 4-year schools. This was the goal of the 5-year schools in agreement with the 1944 recommendation of the ASEE committee on "Engineering Education after the War."

In general, Fig. 1 shows that the 5-year engineering colleges have met the 20% of 4-years non-technical content and have maintained their objectives of giving a

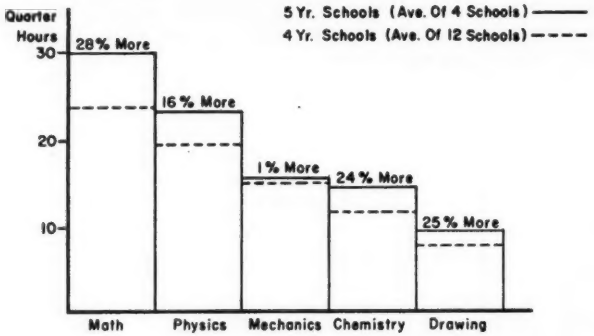

FIG. 3. Comparison of fundamentals in average electrical engineering curricula.

professional type technical education comparable to or better than they were doing previously. They have not invaded the fundamentals.

Fig. 2 compares the average (or composite) electrical curricula in four 5-year schools and in twelve 4-year schools. The figure shows that the comparison is roughly the same as for the composite engineering curricula in Fig. 1.

Here, too, the non-technical content is 20+% of prevailing 4-year content with 16% more fundamental content, 33% more electrical engineering content and 42% more other engineering content.

Figure 3 may be of interest in showing the comparison of fundamental content in the composite 5- and 4-year electrical engineering curricula. The greatest difference in fundamental content is in mathematics with 28% more in 5-year curricula. There are sizeable increases, too, in chemistry and drawing. There is practically no change in the mechanics content. This figure on mechanics may be an unavoidable error in interpreting college catalogs due to the varying pattern of the departmental location of mechanics courses in various institutions. It may be that in some institutions mechanics is "hidden" in the "other engineering" category.

VI. *Conclusion*

No school goes to 5 years lightly. It requires solemn soul searching. There comes a day and time when the task is too great to temporize with tradition and improvisations. That day is here—that time has come. It is the dawn of a new day.

TIMELY TIPS

Open-Book Examinations

By RALPH H. UPSON

Professor of Aeronautical Engineering, University of Minnesota

Professor Ross's interesting article in the October issue, "A Procedure for Teaching Fundamentals" presents, it would seem, some fundamentals themselves, not merely a procedure for teaching them. In this otherwise excellent article, it is somewhat bewildering at first sight to find the author advocating closed-book examinations, which have often been opposed for the very reasons cited by the author in their favor. To me, and I think to most engineering educators, the closed-book examination is rapidly becoming an outworn tool; but quite apparently, there is still room for discussion of the subject. Hence this appeal on behalf of open-book examinations for *all* engineering students.

Although it is realized that the positive approach is in most cases better than the negative one, it seems that in this case the merit of the natural, straightforward, open-book quiz or examination is most convincingly shown by pointing out the serious shortcomings of any arbitrary rule unnecessarily restricting the students' source material. Professor Ross's plea for teaching a student "to think by himself" is certainly a worthy objective on which there can be no dispute. I think it should be established at the outset, however, that encouraging a student to think by himself is possible with either type of test. Any reasonably competent and resourceful teacher with some practical engineering experience will be able to devise basic, thought provoking problems which will put the student on his own responsibility, regardless of whether the quiz is open or closed book. What then is the particular reason for banning consultation of books and notes directly? I see *no* reason for such a restriction beyond the static inertia of outworn custom, or to make the preparation and grading of examinations easier for overworked teachers. On the other hand, there are several very serious disadvantages, as follows:

1. The closed-book restriction is unrealistic. An engineer is *expected* to use books—for what they are worth, as aids to his own thinking, not as substitutes for it. If a quiz is properly designed, a student learns at the first trial that he cannot "bull" through by virtue of a pile of books and notes.

2. The same restriction makes memory work an unduly important function. It puts emphasis on the acquisition of information rather than on its use, and to that extent may actually discourage original thinking. Convenience and use are the only proper criteria for what is worth remembering.

3. Practice in the use of sound engineering resourcefulness is aided by every different source of information at the student's command. To deny him such a reasonable privilege as consulting his own notes and books, when most enlightened teachers now grant it, seems to him arbitrary, unreasonable and unfair.

4. As the average student sees it, the closed-book restriction penalizes the honest student in favor of the "successful" cheater. Intellectual honesty is so highly important in the engineering profession that *any* opposite influence should be

eliminated if at all possible. I have been the recipient of enough student opinion to be sure that this object is in fact greatly aided by the open-book privilege.

Instead of setting up unnecessary restrictions, how much better it would be, and how much more conducive of the student's cooperation and initiative, for the teacher himself to serve not as a proctor but as a consultant? Let him imagine that he is running an engineering office; the students are his staff, to whom he assigns engineering problems; then let him act accordingly and grant to each the use of all reasonable facilities, including his own cooperation!

In furtherance of the above mentioned analogy, some experiments have even been made in practical means of allowing consultation between students during an examination. The results, while interesting and indicative of possibilities, are not as yet thought conclusive enough to justify a definite stand on this particular issue.

One further point seems worth noting. Original thinking may be very *interesting* work, but according to accepted usage (psychological rather than mechanical) it is still work! And for the teacher to do any *less* thinking, and expect the students to do *more*, does not quite make sense. So, with examinations: on the positive side, they should be thought provoking, instructive *and* revealing. This goal sets up no royal road to a life of ease for the teacher; but it is a challenge to integrate quizzes and examinations into the general educational effectiveness of a modern engineering course.

Derivation of Formula for Right Triangles with Integral Sides

By W. E. HOWLAND

Professor of Sanitary Engineering, Purdue University

A derivation of the formula presented by F. C. Bragg for obtaining "Right Triangles with Integral Sides," in his recent article of that title in this journal may be of interest and of some value since one is more likely to recall a method than a formula.

Let the two legs of a right triangle be k and m and the hypotenuse be $k\text{-}m+n$. Then $k^2+m^2=k^2+m^2+n^2-2km+2kn+-2mn$. Therefore, $2km+2mn=n^2+2kn$. Now, and for the remainder of this discussion, assume that n and k are whole numbers; then the right hand side of this equation is a whole number and the left also because it is equal to it. Consider now another right triangle similar to the first, but whose sides are each proportional to the corresponding sides of the first triangle in the ratio $(2k+2n)$ to 1. The sides of this right triangle will then be $2k^2+2kn$ a whole number, $2km+2mn$ equals n^2+2kn, a whole number, and $k(2k+2n) \quad -m(2k+2m)+n \quad (2k+2n)$, a succession of whole numbers, equals $(2k^2+2kn)-(n^2+2kn)+(2kn+2n^2)=2k^2+2kn+n^2-$ also a whole number.

By assuming the sides of the original triangle to be k, m, and $k+m-n$ and using similar methods, one may obtain the following somewhat different, but I think equally useful, formulas for the sides of a right angle triangle which are whole numbers when k and n are whole numbers: $(2k^2-2kn)$, $(2kn-n^2)$ and $(2k^2-2kn+n^2)$.

THE T-SQUARE PAGE

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DEVOTED TO THE INTERESTS
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Let's Face the Music

By J. GERARDI

Chairman, Division Engineering Drawing

Those who have attended the recent meetings of the Drawing Division immediately recognize a perplexing atmosphere which seems to disturb our membership. Even the casual visitor discovers, before too long, that the drawing teachers are very much concerned about problems such as:

1. The misunderstanding which seems to exist between the engineers, educators and teachers as to the value of our present drawing courses in the engineering curricula.
2. The thoughts which have been expressed by some that drawing is of more importance to one branch of engineering than to another.
3. The problems concerning the amount of mathematics and other sciences which should be integrated into a course of graphics.
4. The assumption that drawing course contents have become static and that very few changes have been made within the past twenty-five years.
5. The impression which some of our friends in A.S.E.E. have that our drawing division feels that the world would come to an end if the slightest suggestion is made to de-emphasize lettering, use of instruments, geometric constructions, etc.

These and similar problems have had their fair share of discussion at our meeting and in all probability should be discussed further. But before we promote this activity, it might be wise to reflect for a moment on whether or not it is worthwhile.

At the convention last summer, Dean Hollister of Cornell University gave one of the most philosophical talks which has been presented before our Division. Although his slides were selected to emphasize the methods used by architects to develop originality and creative thinking, several in the audience were more interested in the lettering and line work which appeared on the slides. Others seem to have thought that this was an opportunity to get an answer to the problem concerning the decreased time allotted to the teaching of drawing. It was evident from the discussion which followed that the problems which were mentioned in the first part of this article are beginning to drown the best efforts of those who have a high regard for drawing courses and the Division's interests at heart.

The problems mentioned above must, of course, be resolved, but we cannot have them overshadow the more important projects which will enhance the prestige of the division.

As all of us know, the Engineers Council for Professional Development has asked A.S.E.E. to undertake an evaluation of engineering education. A committee with Dr. I. E. Grinter as chairman has been appointed to make the evaluation. The primary objective of this committee will be to determine why the basic pattern of engineering education has remained fixed and to determine whether new patterns of curricula are required to meet the rapid developments in science. One may hazard a guess that Dr. Grinter's report will not only have a profound influence on engineering curricula, but will also have a pronounced effect on the contents of technical courses.

Drawing Courses May Change Their Complexions

Drawing courses will be no exception. They too must be geared to the more recent advances in science and technology. Because of the short supply of engineers, the number of graduates who will begin their careers at the drafting board will decrease. Not only will they be expected to apply their knowledge of mathematics and science to engineering developments, but they may be expected to supervise the work of draftsmen. Hence, it may be predicted that drawing courses may of necessity change their complexions. No longer will the description of drawing courses in University bulletins list lettering, use of instruments, geometric constructions, etc., but may emphasize items such as—the study of shapes and form employing various materials to develop creative thinking, graphical solutions of engineering problems, supervision of draftsmen, etc. This change will not occur overnight, but we can expect something of this nature to develop in the near future.

Hence, let us "face the music," accept the challenge and direct our energies toward more efficient use of the time we have: let us revitalize our course content to such an extent that those whose courses have been curtailed may be given an opportunity to regain the necessary time to teach their courses properly.

The Drawing Division has served the A.S.E.E. for twenty-five years. Its activities and the resourcefulness of its members is well known. The many projects and studies which have been sponsored by the Division have been worthy of publication and have had a great influence in unifying course work with the demands of industry. No other Division of A.S.E.E. has a publication similar to the *Journal of Engineering Drawing*; moreover, our magazine enjoys world-wide circulation and has not shown a financial loss for the past fifteen years. These and other accomplishments of our Division are due to the initiative, loyalty and hard work of the men who founded and have led the Division.

In order to uphold the traditions of the past, and to encourage discussion, exchange of ideas, and active participation of our members, your officers this coming year, knowing that they can count on the excellent cooperation which has been given in the past, will initiate a program which will suggest a pattern of thinking along the following lines:

1. A critical review of the contents of present drawing courses and recommendations for the future.
2. A thorough study of the new requirements which the engineering profession will impose on graduates because of the short supply of engineers.
3. Divisional participation with Dr. Grinter's committee on evaluation of engineering education.
4. Methods of improving teaching and raising the level of instruction in graphics. Professor F. A. Heacock and his committee on advanced graphics has completed and published a report on "Graphical Methods for Solving Engineering Problems." This report will receive special attention.

The above suggestions are by no means fixed or final, and your chairman as well as your executive committee will welcome any suggestions which will improve the activities of the Division.

TEACHING POSITIONS AVAILABLE

The following rules were adopted by the General Council of the ASEE:

1. The privilege of advertising for teaching positions is extended only to colleges and technical institutes which are either Active or Affiliate Institutional Members of the ASEE.

2. Advertisements must be for positions available only. No advertisements will be accepted for an individual seeking a job.

3. Advertisements should not specify salaries.

4. Advertisements must be submitted not later than the first day of the month preceding the month of issue.

5. Because of limited staff, the ASEE headquarters cannot maintain personnel files or supply detailed information about jobs. In replying to blind ads, address letters to American Society for Engineering Education, Northwestern University, Evanston, Illinois and give blind ad number.

6. Information and rates for advertising in the Journal can be received by writing ASEE Headquarters.

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Section Meetings

Section	*Location of Meeting*	*Dates*	*Chairman of Section*
Allegheny	West Virginia University	April 17–18, 1953	C. H. Cather, West Virginia University
Illinois-Indiana	Rose Polytechnic Institute	May, 16, 1953	H. A. Moench, Rose Polytechnic Institute
*Kansas-Nebraska	Kansas State College		M. H. Barnard, University of Nebraska
Michigan	Detroit Institute of Technology	May 9, 1953	C. C. Winn, Detroit Institute of Technology
Middle Atlantic	University of Delaware	May 2, 1953	C. Bonilla, Columbia University
Missouri	Washington University	April 11, 1953	G. F. Branigan, University of Arkansas
National Capital Area	Howard University	May 9, 1953	L. K. Downing, Howard University
New England	University of Vermont	Oct. 10, 1953	E. T. Donovan, University of New Hampshire
North Midwest	Marquette University	Oct. 9–10, 1953	A. B. Drought, Marquette University
Ohio	University of Cincinnati	May 2, 1953	H. K. Justice, University of Cincinnati
Pacific Northwest	Washington State College	April 24–25, 1953	J. P. Spielman, Washington State College
Pacific Southwest	San Jose State College	Dec. 29–30, 1953	C. M. Duke, University of California at Los Angeles
Rocky Mountain	University of Colorado	April 11, 1953	C. A. Hutchinson, University of Colorado
*Southeastern	North Carolina State College		D. V. Terrell, University of Kentucky
Southwestern	University of New Mexico	April 3 & 4, 1953	M. L. Ray, University of Houston
Upper New York	Rochester Institute of Technology	October, 1953	F. E. Almstead, State University of New York

Members of the Society are welcome at all Section Meetings

* No Date Set.

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BACKER, GERALD H., Associate Professor of Aeronautical Engineering, University of Alabama, University, Ala. C. H. Bryan, W. K. Rey.

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BALL, BRYAN W., Instructor in Mechanical Engineering, University of Houston, Houston, Tex. W. B. Lowe, M. L. Ray.

BAUER, DAVID E., Assistant Professor of Industrial Engineering, Pennsylvania State College, State College, Pa. E. S. Roscoe, C. E. Bullinger.

BIBERSTEIN, FRANK A., Professor of Civil Engineering, Catholic University of America, Washington, D. C. J. W. C. Michalowicz, H. P. Gallogly.

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CARTER, RICHARD J., Instructor in Electrical Engineering, Northeastern University, Boston, Mass. L. F. Cleveland, W. T. Alexander.

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WILSON, J. S., Personnel Manager, Corn Products Refining Company, Argo, Ill. A. B. Bronwell, W. R. Woolrich.

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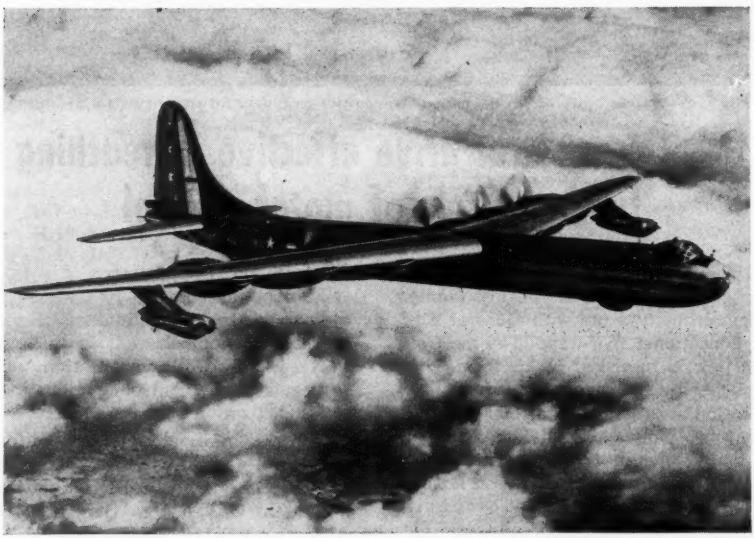

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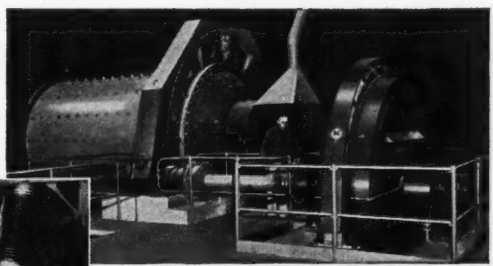

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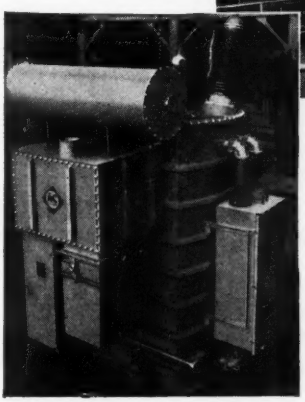

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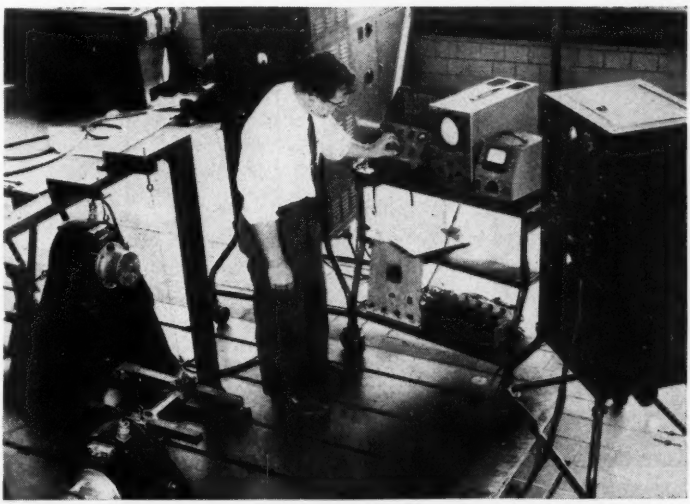

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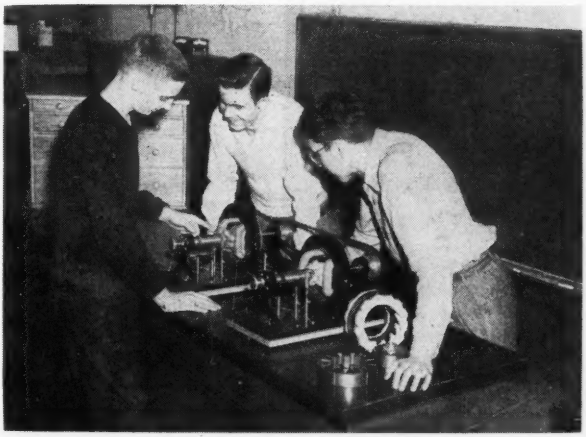

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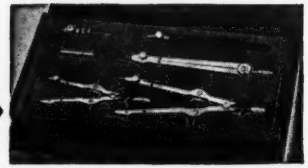

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